

16 February 2007

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Dear Sirs

British Patent Application No. 0422749.2
Haase, Richard A.
Our Ref: LAS01677GB
Your Ref: 0920/002-GB

We enclose herewith the Certificate of Grant of the patent granted on this application.

Details of the patent are as follows:-

GB PATENT NUMBER : 2407372
DATE OF PATENT : 10 April 2003
PATENTEE : Haase, Richard A.

We advise that any article made in accordance with this patent be marked with the patent number.

The duration of the patent will be twenty years from the date of the patent shown above, subject to the payment of renewal fees.

Yours faithfully

Gill Jennings & Every LLP

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British Patent Certificate of Grant

Number 2407372 Dated 10 April 2003

Proprietor Haase, Richard A.

Reference 0920/002-GB

Duration 20 years from the above date subject to the payment of renewal fees.



Certificate of Grant of Patent

Patent Number: GB2407372

Proprietor(s): Richard A Haase

Inventor(s): Richard A Haase

This is to Certify that, in accordance with the Patents Act 1977,

a Patent has been granted to the proprietor(s) for an invention entitled
**"Water combustion technology-methods,processes,systems and
apparatus for the combustion of hydrogen and oxygen"** disclosed in
an application filed **10 April 2003**.

Dated 14 February 2007



Ron Marchant
Comptroller General of Patents,
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UNITED KINGDOM PATENT OFFICE

The attention of the proprietor(s) is drawn to the important notes overleaf.

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Blank Patent Forms 12/77 and fee sheets (FS2) can be requested by post from The Central Enquiry Unit, The Patent Office, Concept House, Cardiff Road, Newport, South Wales NP10 8QQ, by telephone on 08459-500505 (Minicom 08459-222250), by fax on 01633-813600 or by e-mail (enquiries@patent.gov.uk). The Forms and fee sheets can also be downloaded from the Patent Office website (www.patent.gov.uk).

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For further information or assistance you can contact the Central Enquiry Unit of the Patent Office as indicated above.



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(54) Title of the invention: **Water combustion technology-methods,processes,systems and apparatus for the combustion of hydrogen and oxygen**

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(58) Field of Search: As for published application 2407372 A viz: Other US: 60/39.05, 39.6, 651, 671 updated as appropriate				

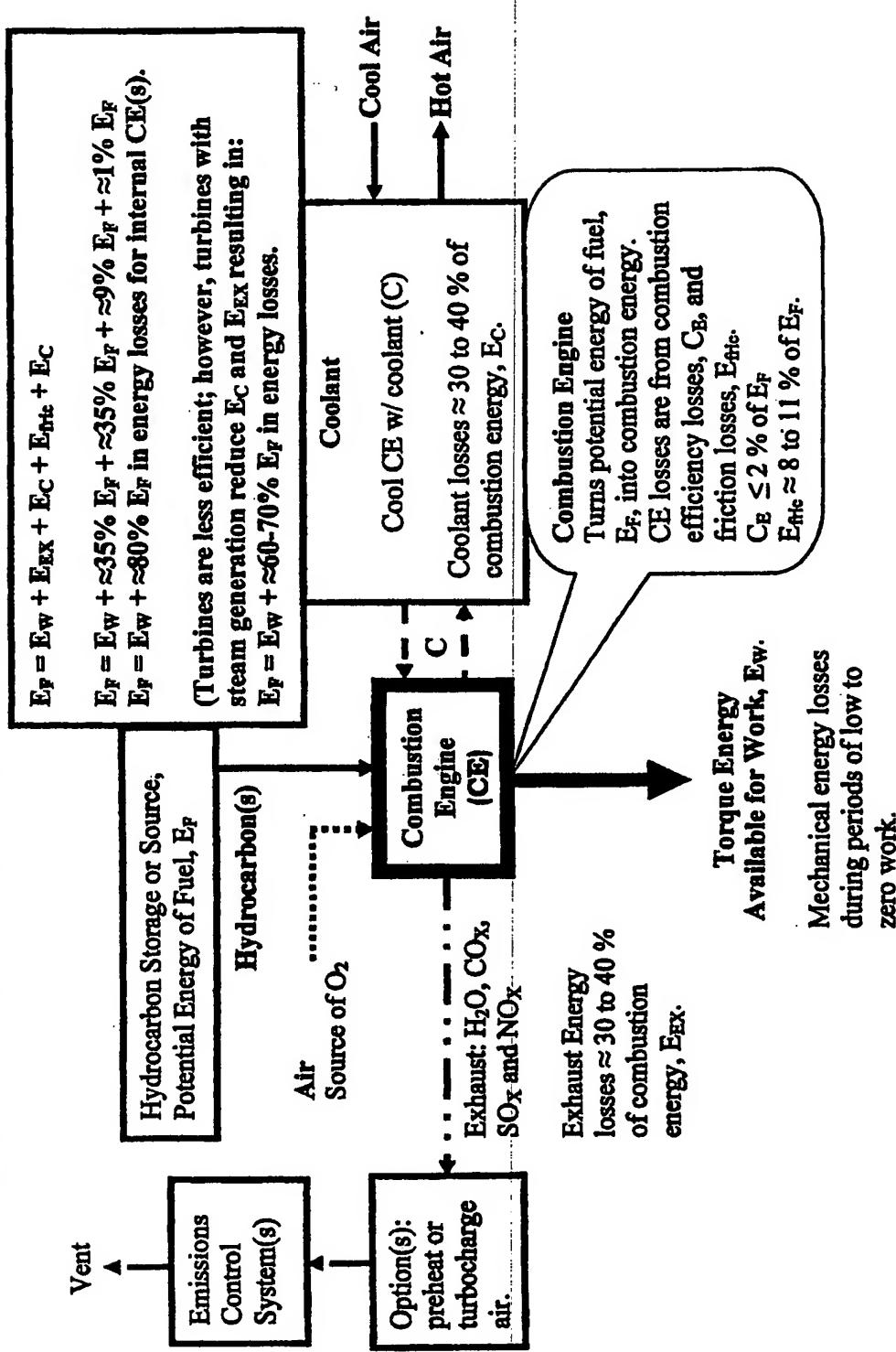
Table 1
WCT Symbols in Figures 1 through 23A

Symbol	Description	Notes
	Combustion Engine	CE can be any combustion design as is known in the art, i.e. internal combustion engine, turbine, furnace, etc. CE combines fuel and ignites fuel with a spark generation device. Fuel is most preferably O ₂ , H ₂ and H ₂ O. Fuel is preferably O ₂ and H ₂ . Fuel can be used in combination with air.
	Gas Compressor	Used in Cryogenic Refrigeration. Designs are plentiful in the art. Compressor symbols: A = Air, D1 = First Distillation, D2 = Second Distillation, O1 = O ₂ , H1 = H ₂ , O = O ₂ Storage and H = H ₂ Storage.
	Joule-Thompson Expansion Valve	Two types are normally used in the art – 1. An expansion valve, 2. A cylinder.
	Separation (Distillation Column)	Diameter and Height dependent upon separation efficiency and loading. Separation efficiency dependent upon compounds separated and column packing. Distillation Temperatures are relative to Separation Operating Pressure. Depending on the desired O ₂ purity, the second O ₂ /N ₂ separation column is optional.
	Heat Exchanger to cool compressed gases	During normal operation, it is preferred that the waste N ₂ is coolant. Depending upon design, upon start-up water may be necessary for an efficient start-up.
	Cryogenic Storage Tank	Tank is to be made of materials known in the art to withstand liquid cryogenic temperatures/pressure of O ₂ and/or H ₂ . Tank may have refrigeration loop per Figure 13, which operates off at least one of: the combustion engine, a battery and a fuel cell.
	Turbine	Depending upon application, turbine is to be turned by steam, air or water movement. Turbine is preferred to generate electricity, preferably driving a generator and/or alternator. It is most preferred that the electricity performs electrolysis.
	Pressure Controller	Pressure controller can be of any design as is known in the art. PC protects downstream equipment from pressure surges. In high pressure surge situations, PC vents to the atmosphere.
	Energy in the form of heat	Energy is transferred (managed) during many methods, processes and systems of this invention.
	Fuel Mixture Controller	H ₂ , O ₂ , H ₂ O, air bypass and engine coolant. Controller manages fuel mixture ratios. H ₂ O ratio in combustion is managed depending upon combustion temperature and/or engine temperature. Air bypass is to be managed depending upon O ₂ tank level. Engine coolant loop dependant on high engine temperature.

Table 1A
WCT Symbols in Figures 1 through 23A

Symbol	Description	Notes
	Clutch	Used to transfer Ew to at least one of a flywheel and a generator. Clutch preferably engages during periods of little to no work and disengaged during periods of work. Design and assembly to be as known in the art.
	Flywheel	Used to store rotational kinetic energy during periods of little to no work; rotational energy to be utilized during periods of work.
	Generator	Used to generate electrical energy. Generator can be of the type to generate an alternating current (A/C), such as in power generation applications or a Dynamo to generate a direct current (D/C) to power electrolysis. A/C current can be turned into D/C with an A/C to D/C converter and D/C can be turned into A/C with a D/C to A/C converter.
	Electrolysis	Electrolysis of H ₂ O to O ₂ and H ₂ is to be performed. Electrolysis is to be performed by methods and systems known in the art of electrolysis. It is most preferred that an electrolyte be present in the H ₂ O to further electrolysis and the efficiency of electrolysis. It is preferred that the electrolysis unit be cooled.
.....	Air Line	Line primarily contains air.
.....	O ₂ Line	Line primarily contains O ₂ .
— — —	N ₂ Line	Line primarily contains N ₂ .
— — —	H ₂ Line	Line primarily contains H ₂ .
— — —	H ₂ O Line	Line primarily contains H ₂ O.
— · — ·	Products Line	Line primarily contains combustion products, preferably H ₂ O, yet can be H ₂ O and X, wherein X is N ₂ , CO _X and NO _X and can contain SO _X .
— — — —	Coolant (C) Line	Line symbol indicates flow of coolant, which is preferably used with electrolysis. C can be used with CE; however this is not preferred. C can be any type as is known in the art; coolant is preferred a mixture of water, glycol, corrosion inhibitor and dispersant.
— — —	Control Line	Electrical or pneumatic line. Electrical wire carrying a small current, preferably 4 to 20 mA. Pneumatic line may carry a gas and/or a under liquid pressure.
— — —	Flow Transmitter & Control Valve	Used in combination with control line and controller (CONT.) to control flow of fuel and/or coolant (C).
	Coolant Radiator	Used to release heat from coolant and pump back to heat source. Preferably used for electrolysis. Preferably used to cool oil for CE. It is not preferred to cool CE.

Figure 2
Traditional Combustion - Combustion Fueled by Hydrocarbon(s) and Air



Combustion Fueled by H₂ and O₂ Having Air as Alternate Source of O₂

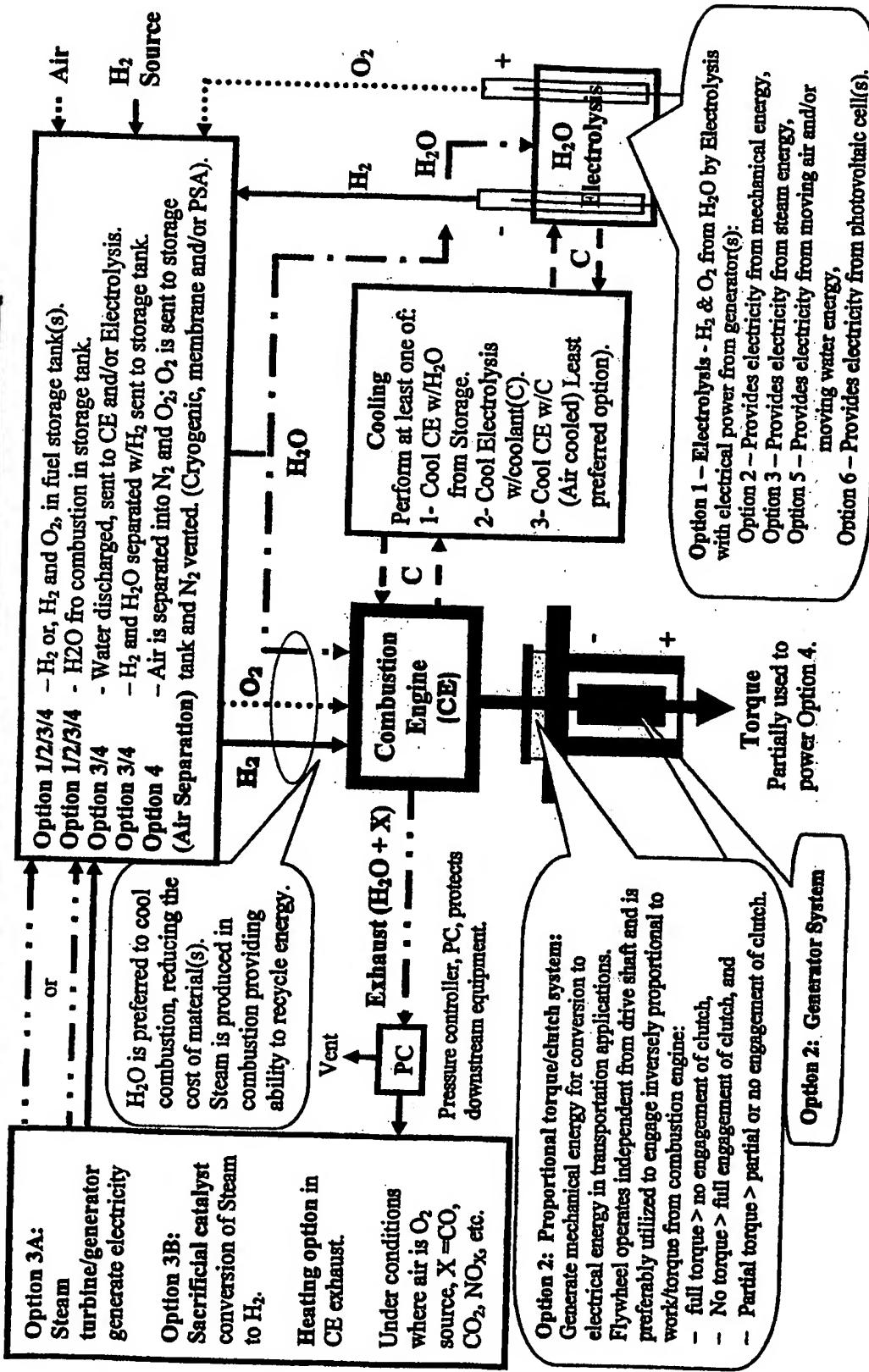


Figure 3
Combustion Fueled by H₂ and O₂ with Air as Alternate- Electrolysis

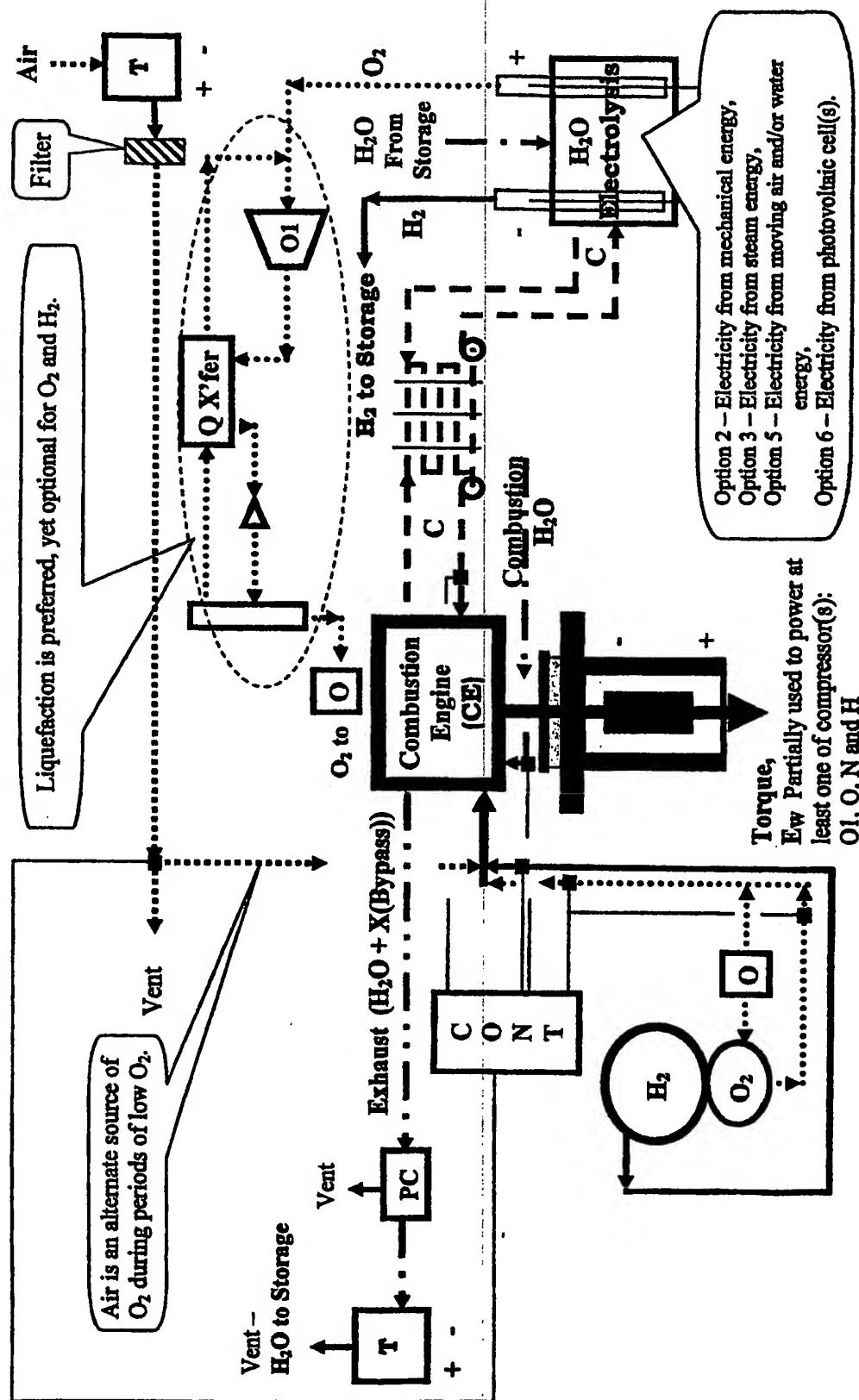


Figure 4
Combustion Fueled by H₂ and O₂ with Air as Alternate – H₂ Catalysis

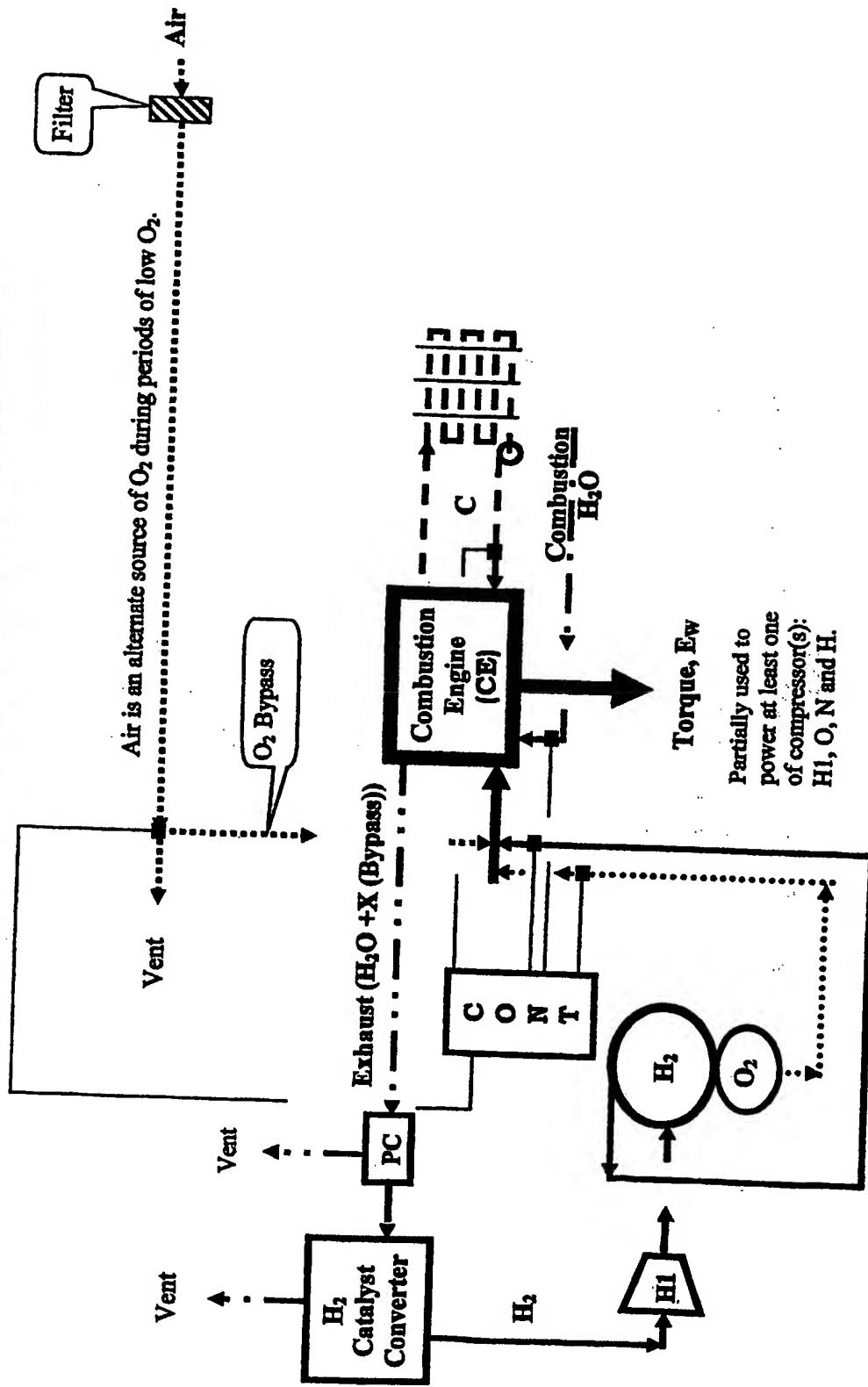


Figure 5
Combustion Fueled by H₂ and O₂ with Air as Alternate - O₂ Distillation

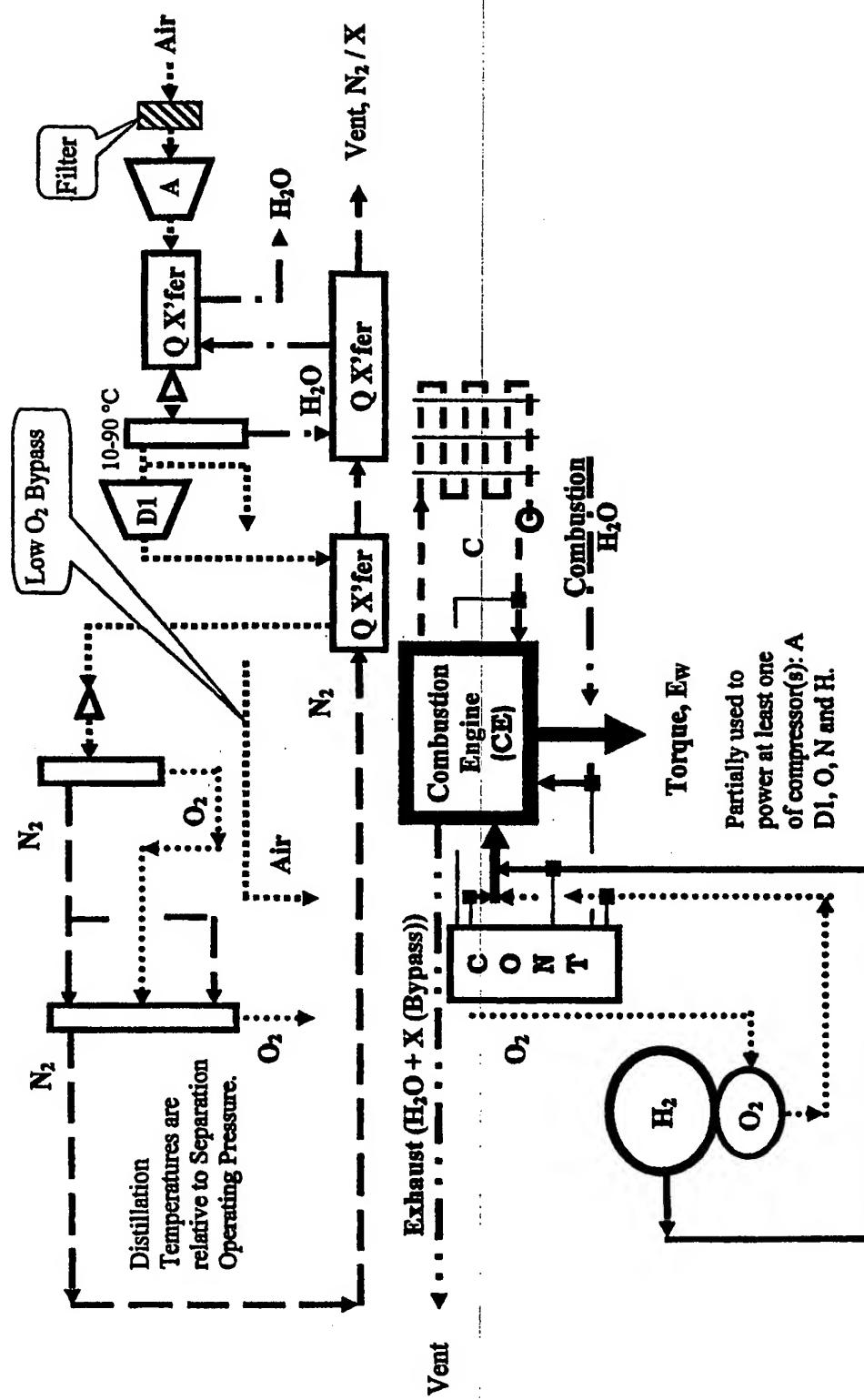
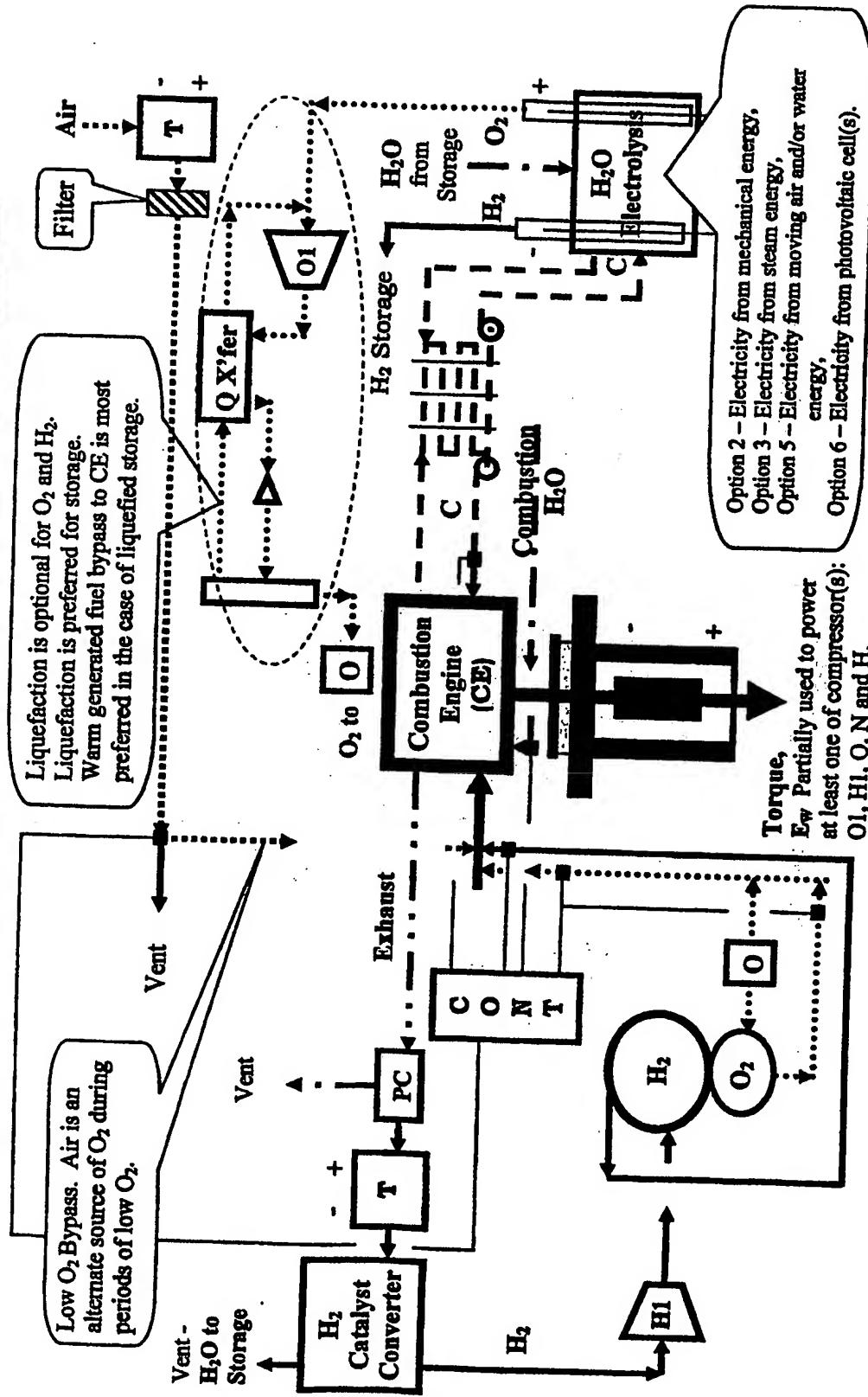


Figure 6
Combustion Fueled by H₂ and O₂ with Air as Alternate – Electrolysis – H₂ Catalysis



Combustion Fueled by H_2 and O_2 with Air as Alternate - Electrolysis - O_2 Distillation

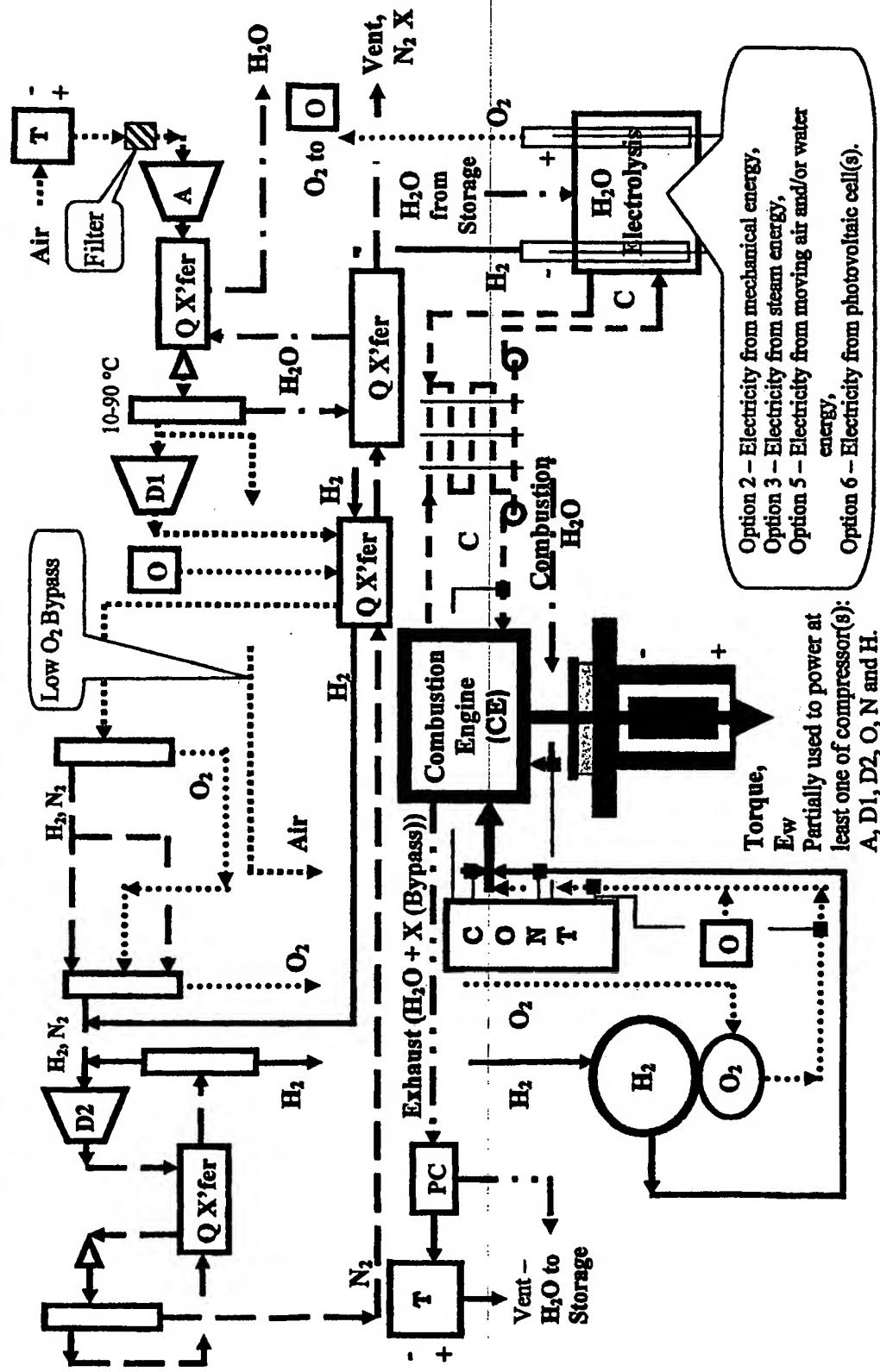


Figure 8
Combustion Fueled by H₂ and O₂ with Air as Alternate - Electrolysis - H₂ Catalysis - O₂ Distillation

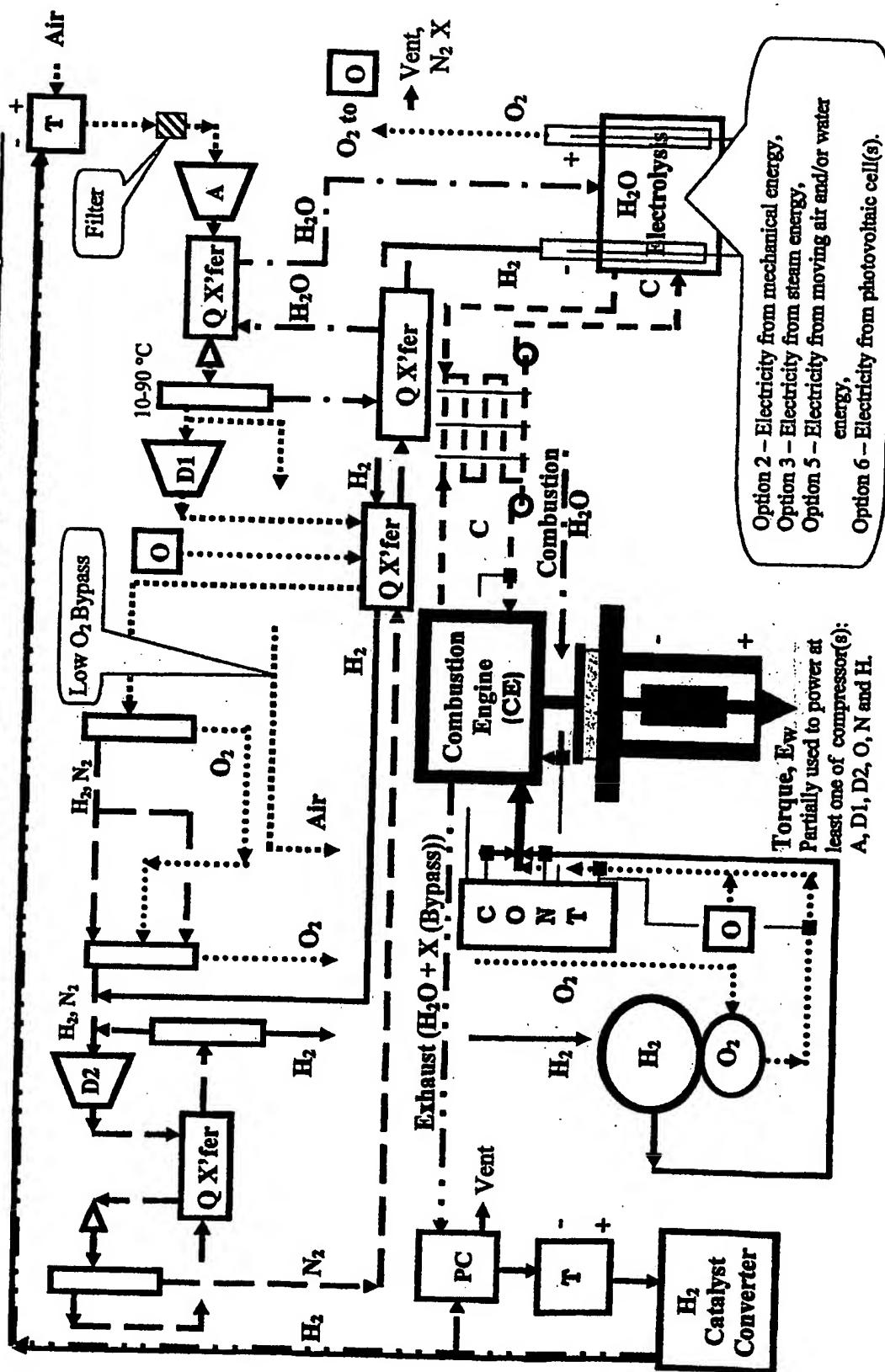


Figure 9
Combustion Fueled by H_2 and O_2 with Air as Alternate - O_2 Separation by Membranes or PSA

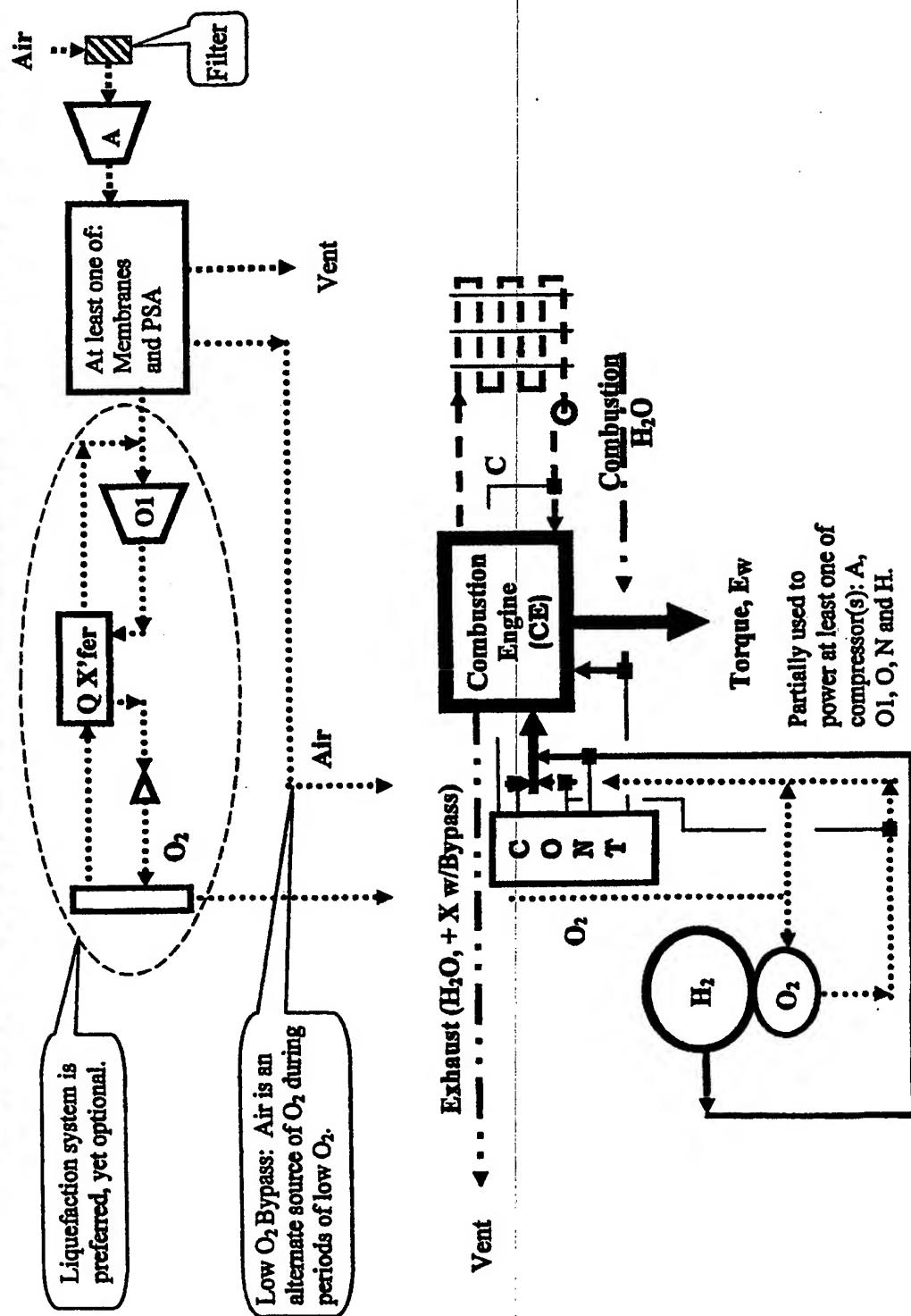


Figure 10
Combustion Fueled by H₂ and O₂ with Air as Alternate - Electrolysis - O₂ Separation by Membranes or PSA

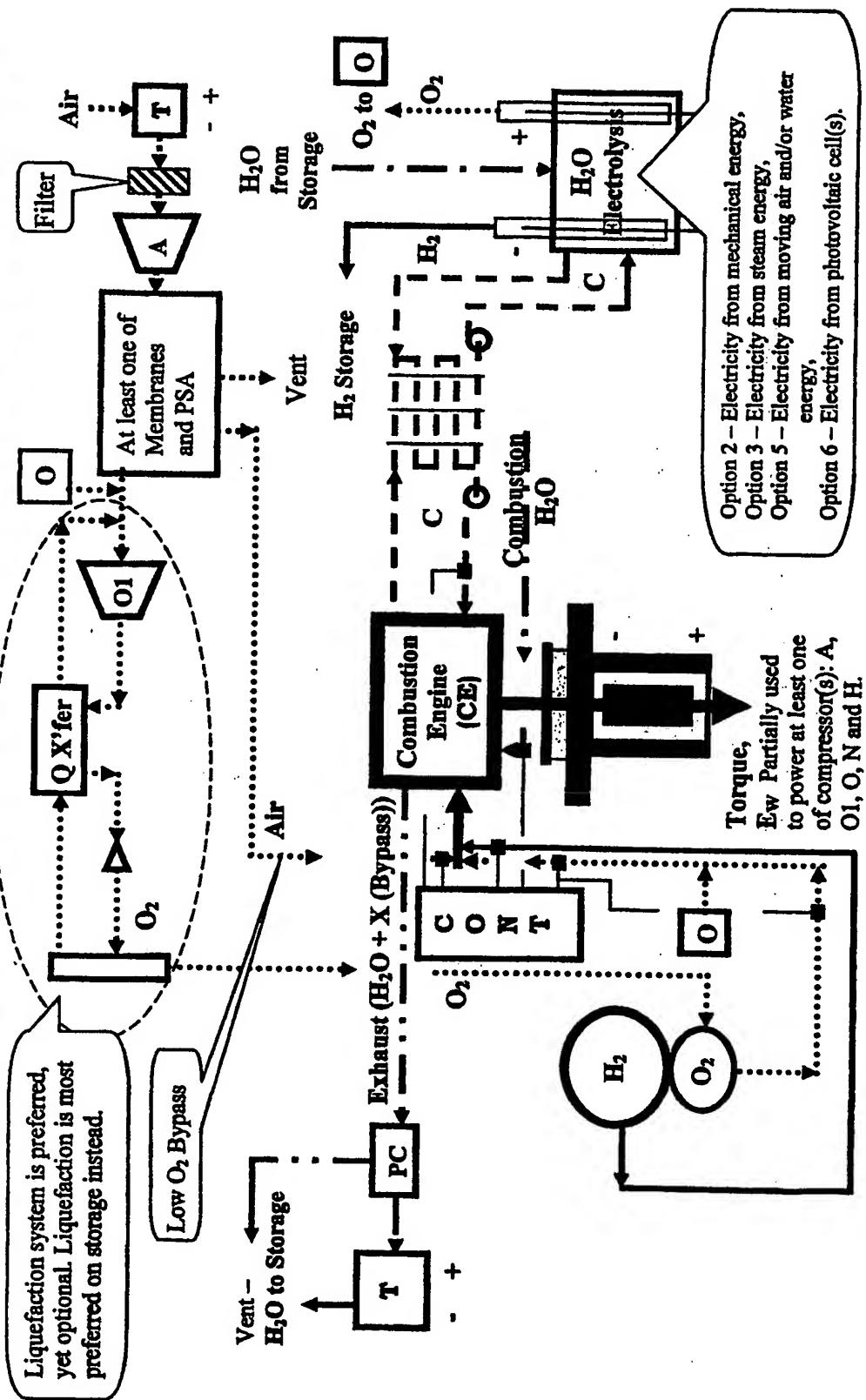


Figure 11
Combustion Fueled by H₂ and O₂ with Air as Alternate - Electrolysis - H₂ Catalysis O₂ Separation by Membranes or PSA

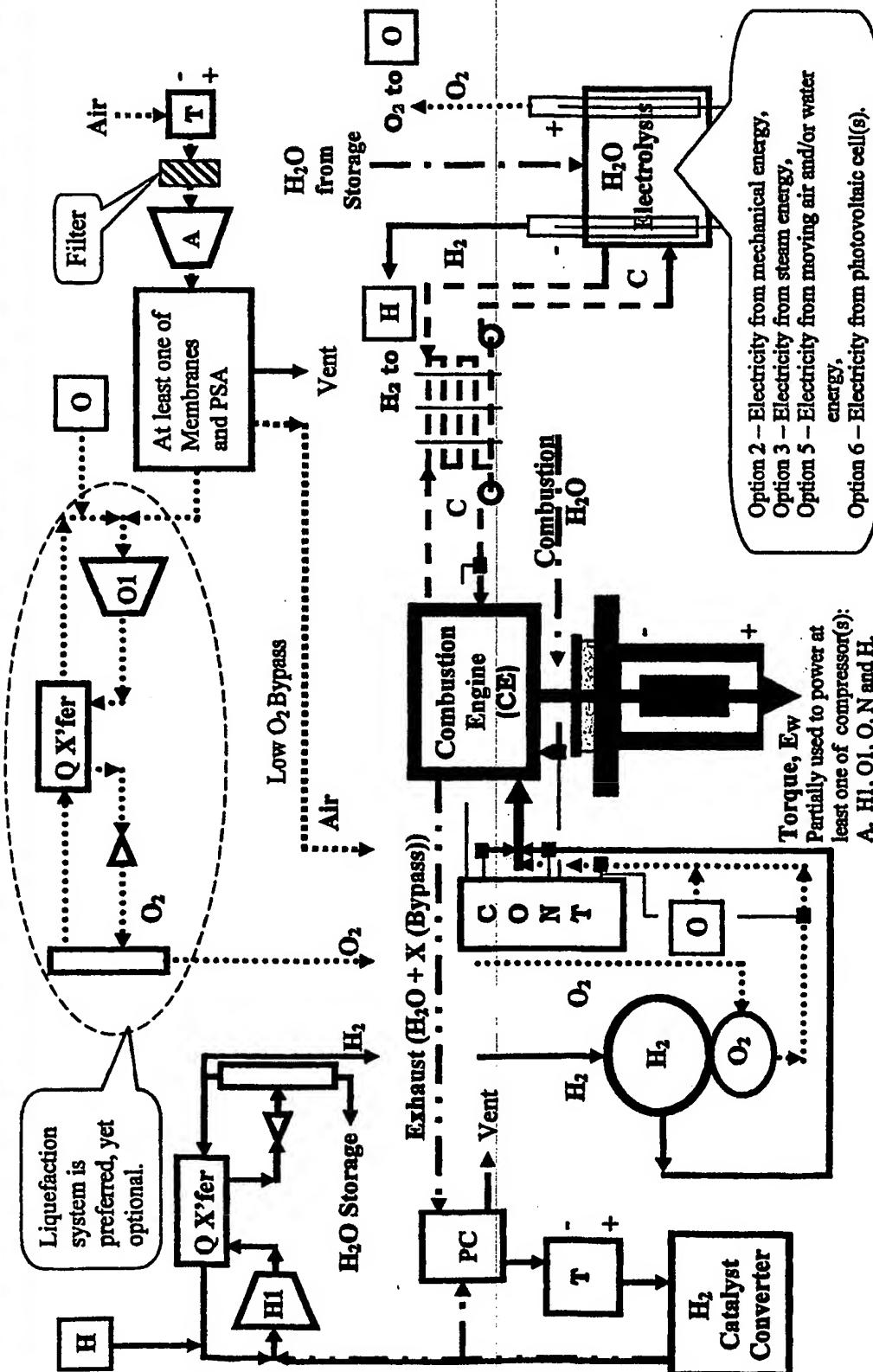


Figure 12 Combustion Fueled by H_2 and O_2 with Air as Alternate - H_2 Catalysis - O_2 Distillation Air

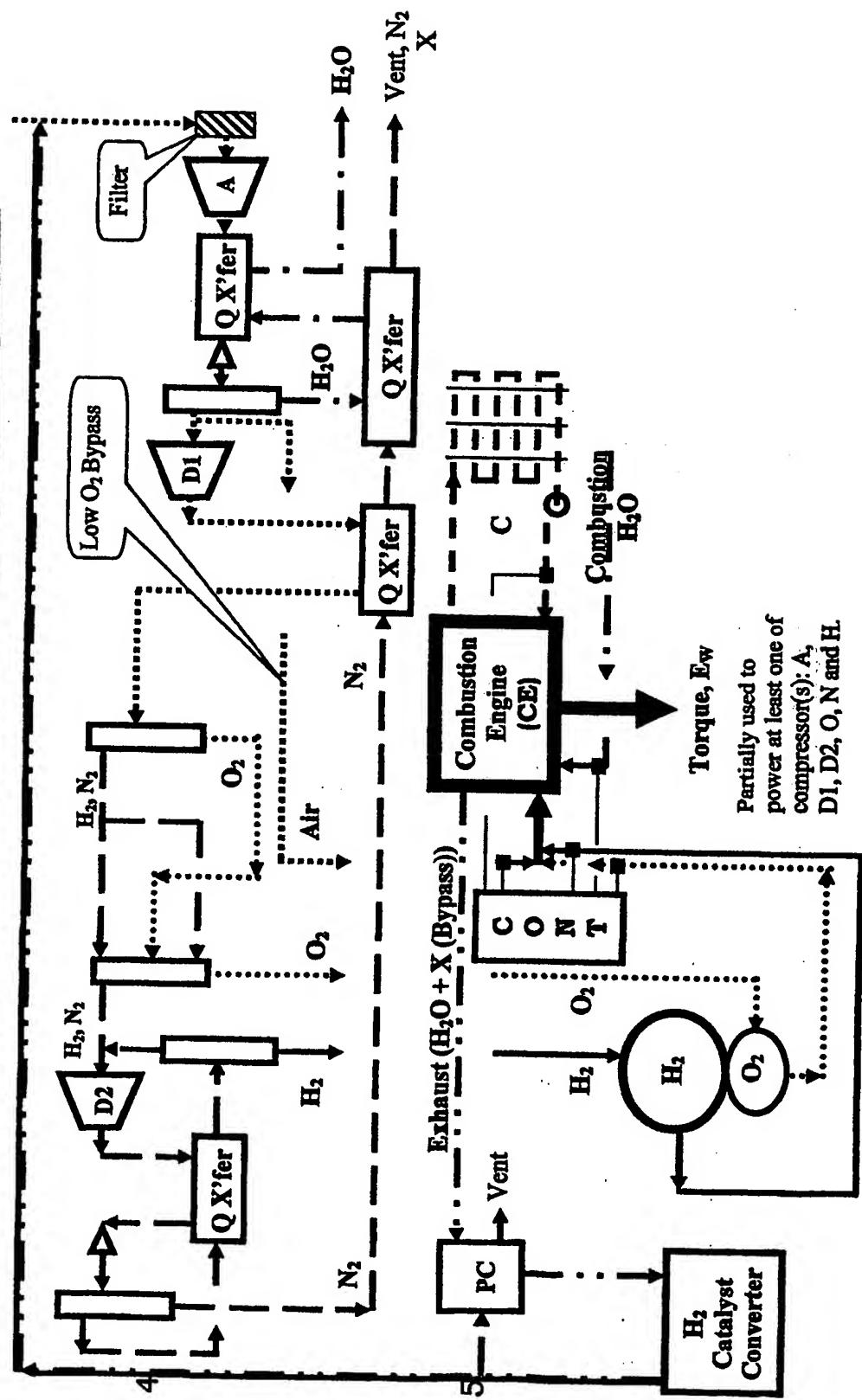


Figure 13
Combustion Fueled by H₂ and O₂ with Air as Alternate - H₂ Catalysts O₂ Separation by Membranes or PSA

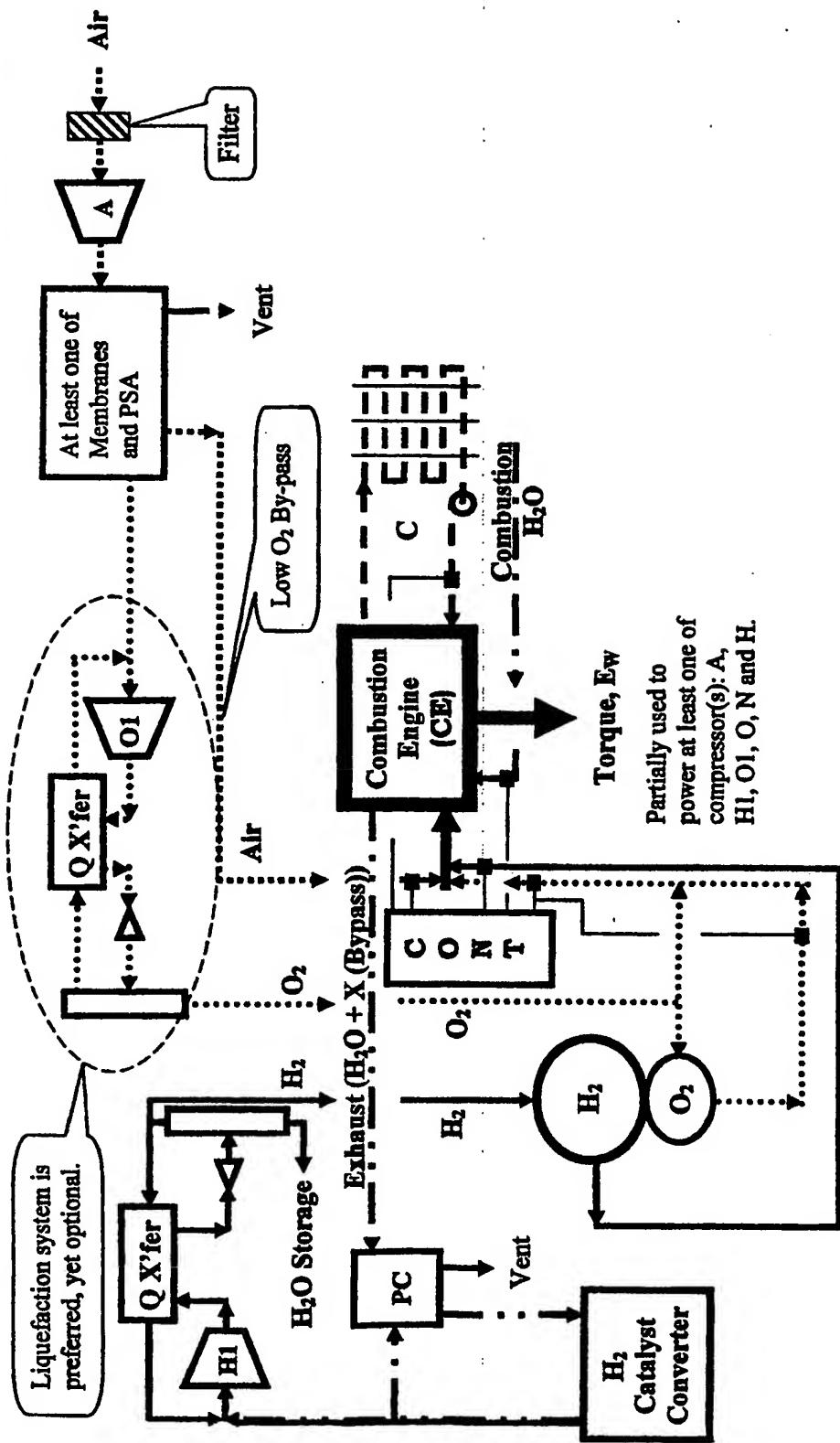


Figure 14
Combustion Fueled by H₂ and O₂ with Air as Alternate - H₂ Catalysis

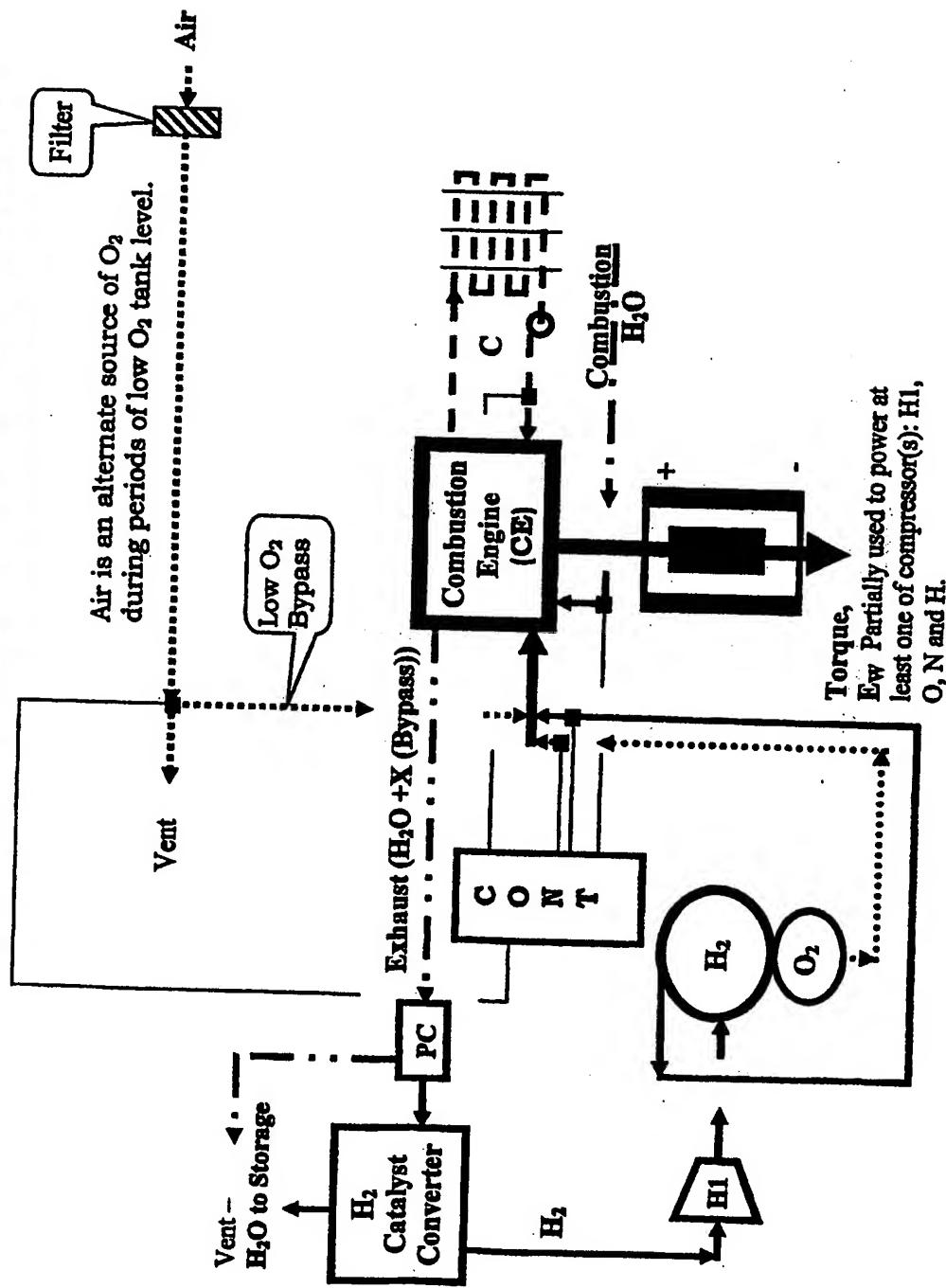


Figure 15
Combustion Fueled by H₂ and O₂ with Air as Alternate - O₂ Distillation

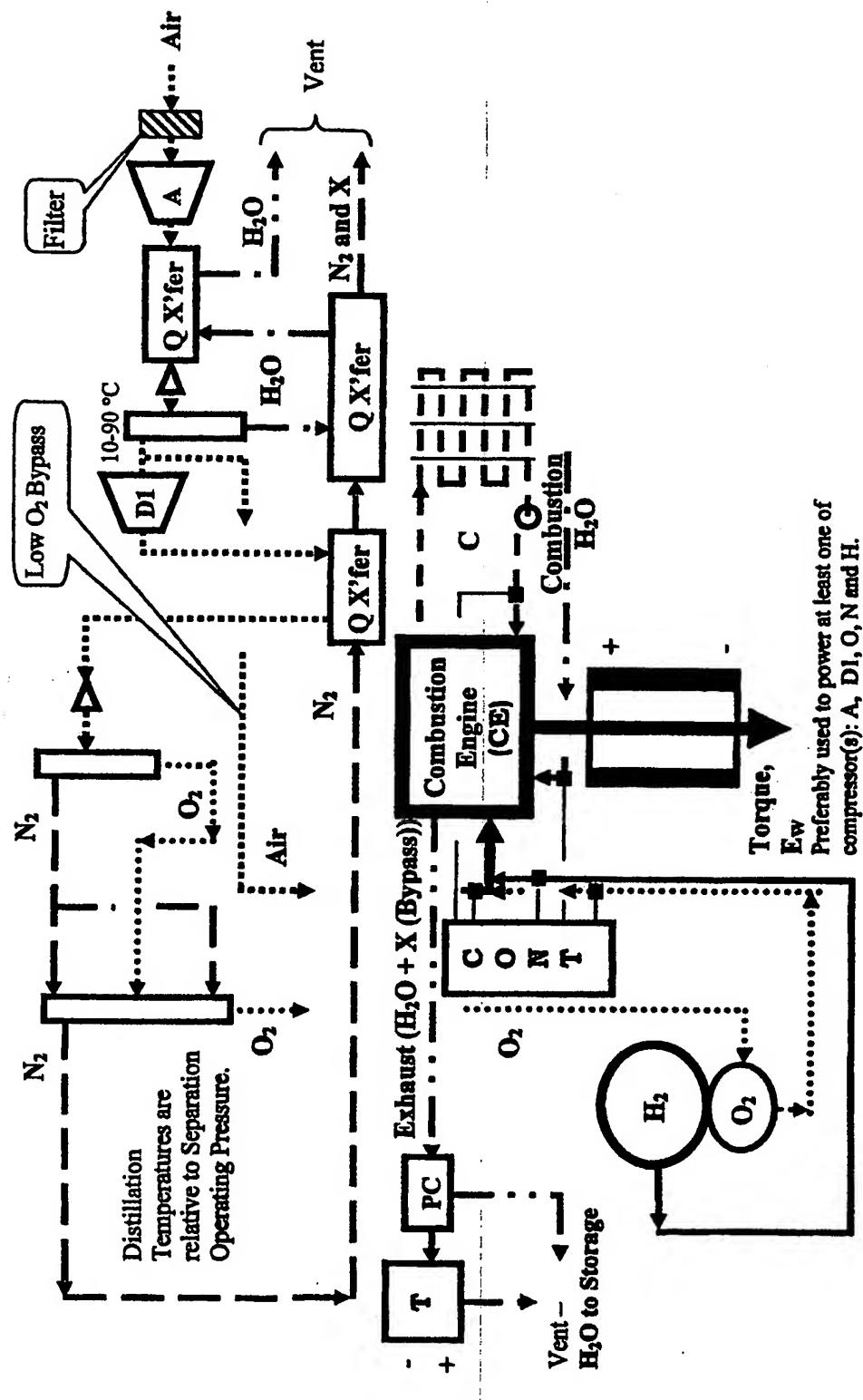


Figure 16
Combustion Fueled by H_2 and O_2 with Air as Alternate - O_2 Separation by Membranes or PSA

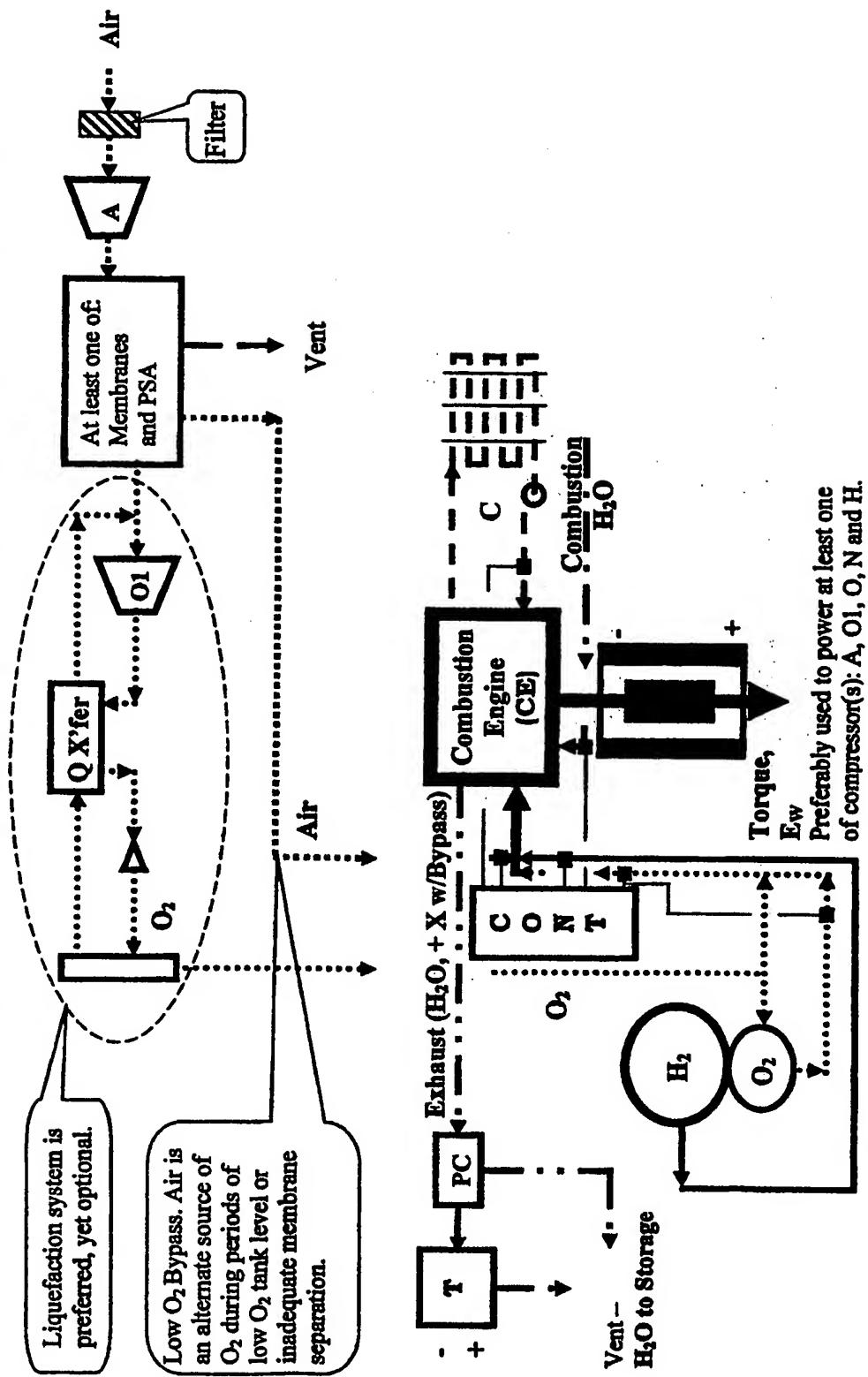


Figure 17
Combustion Fueled by H₂ and O₂ with Air as Alternate - H₂ Catalysis - O₂ Distillation

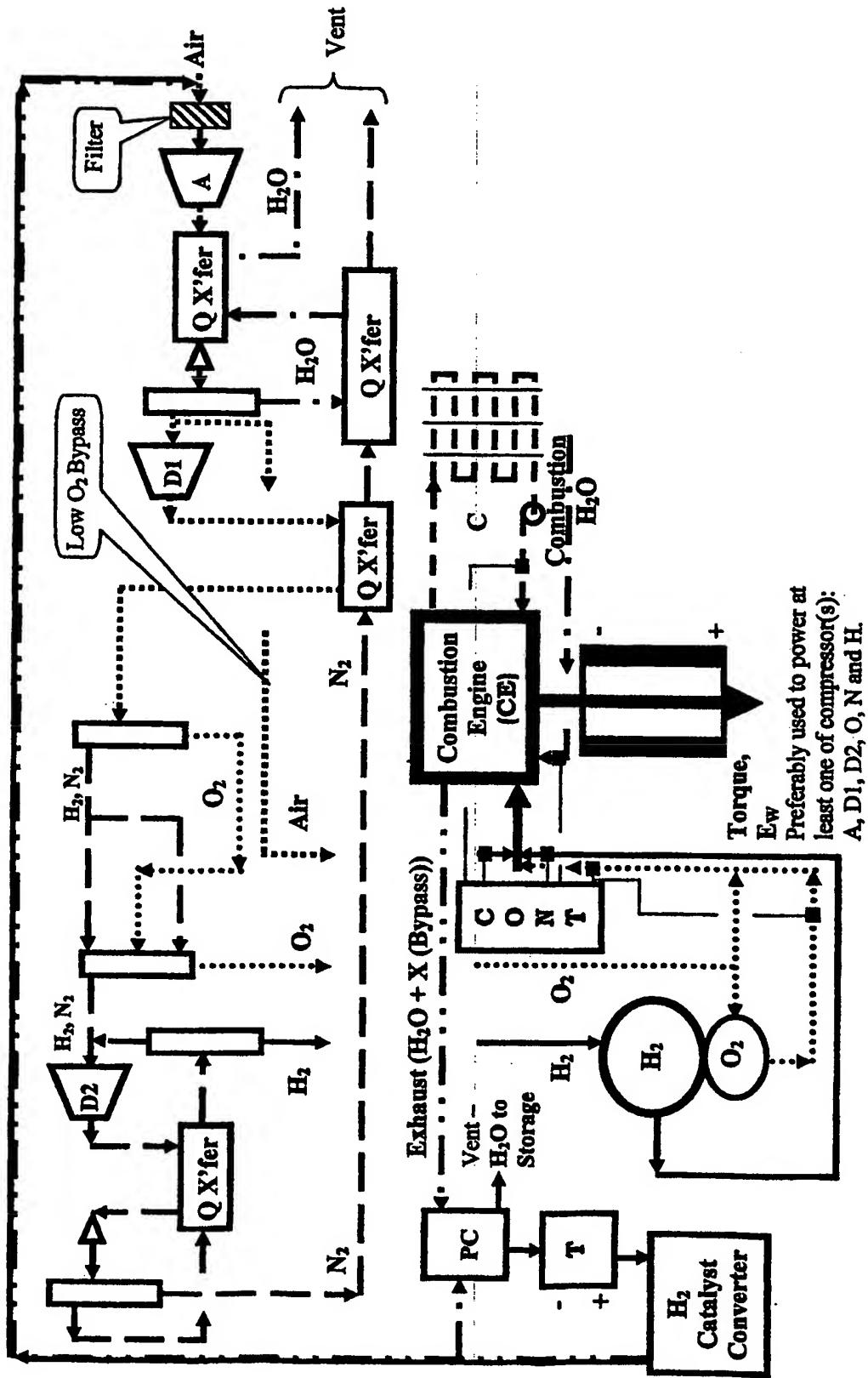


Figure 18 Combustion Fueled by H_2 and O_2 with Air as Alternate - H_2 Catalysis O_2 Separation by Membranes or PSA

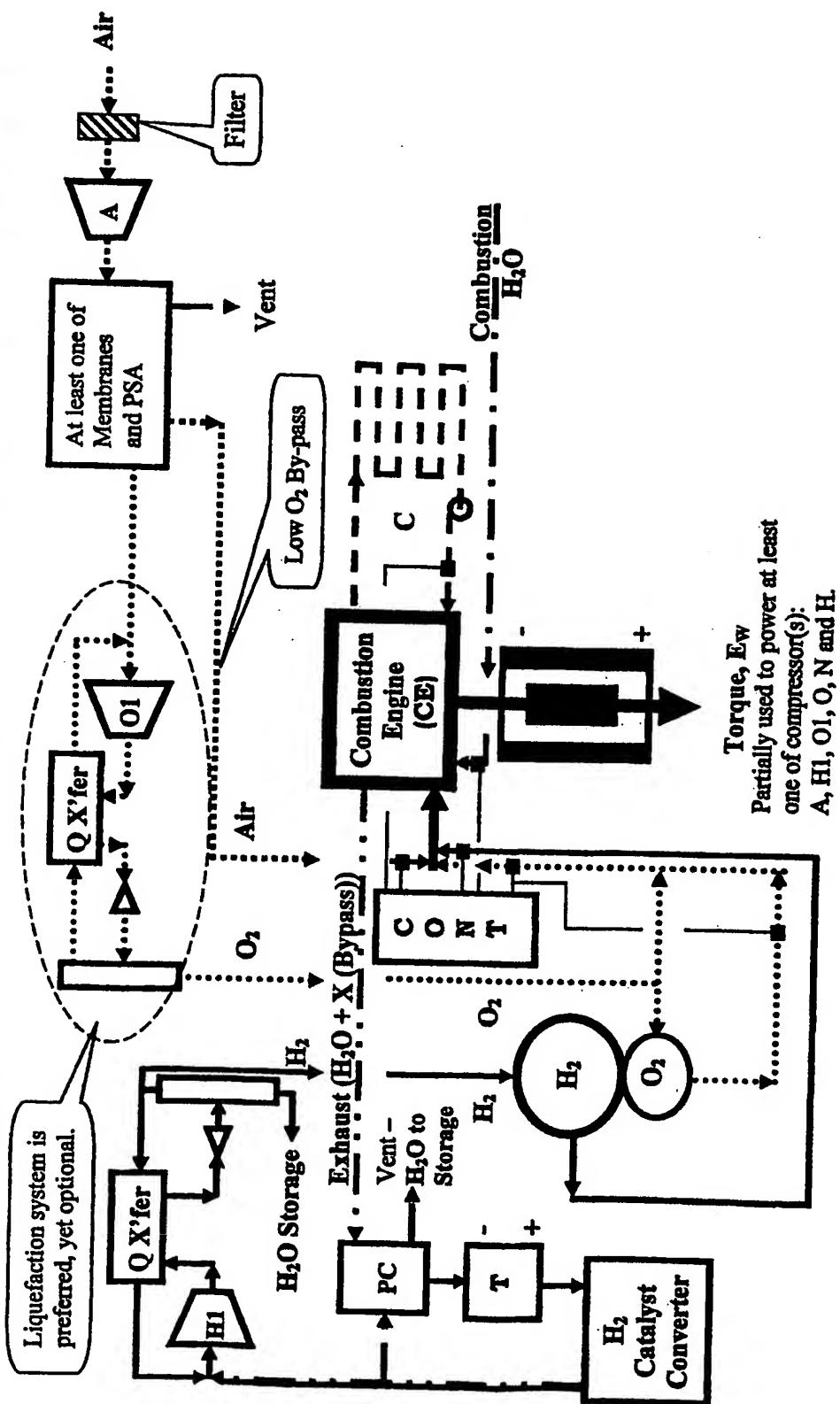


Figure 19
Combustion Fueled by H₂ and O₂ and/or Air - Fuel Preheating

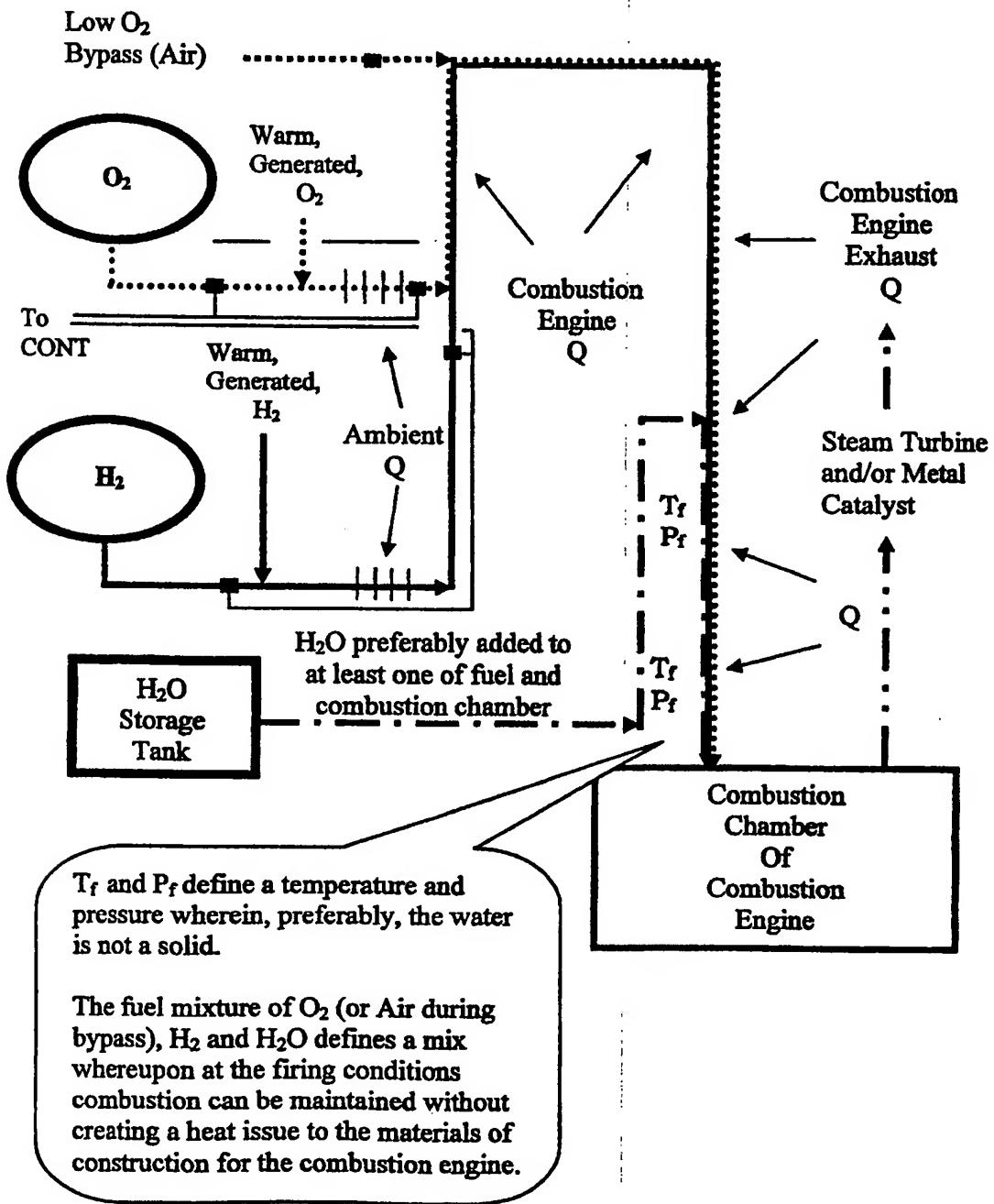


Figure 21
Steam Turbine Configuration(a)

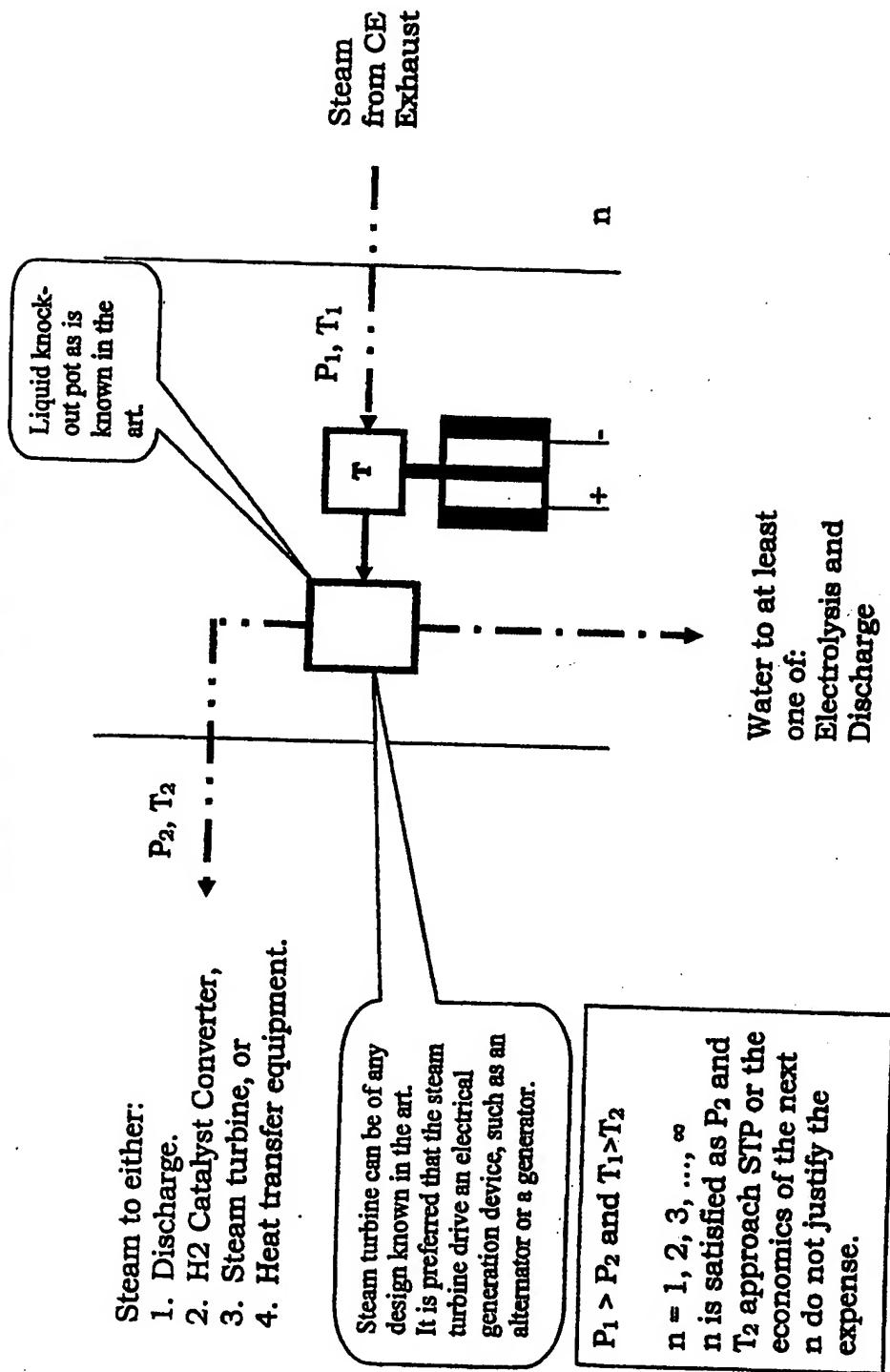


Figure 21A
In-Line Combustion and Steam Turbine Configuration(s)

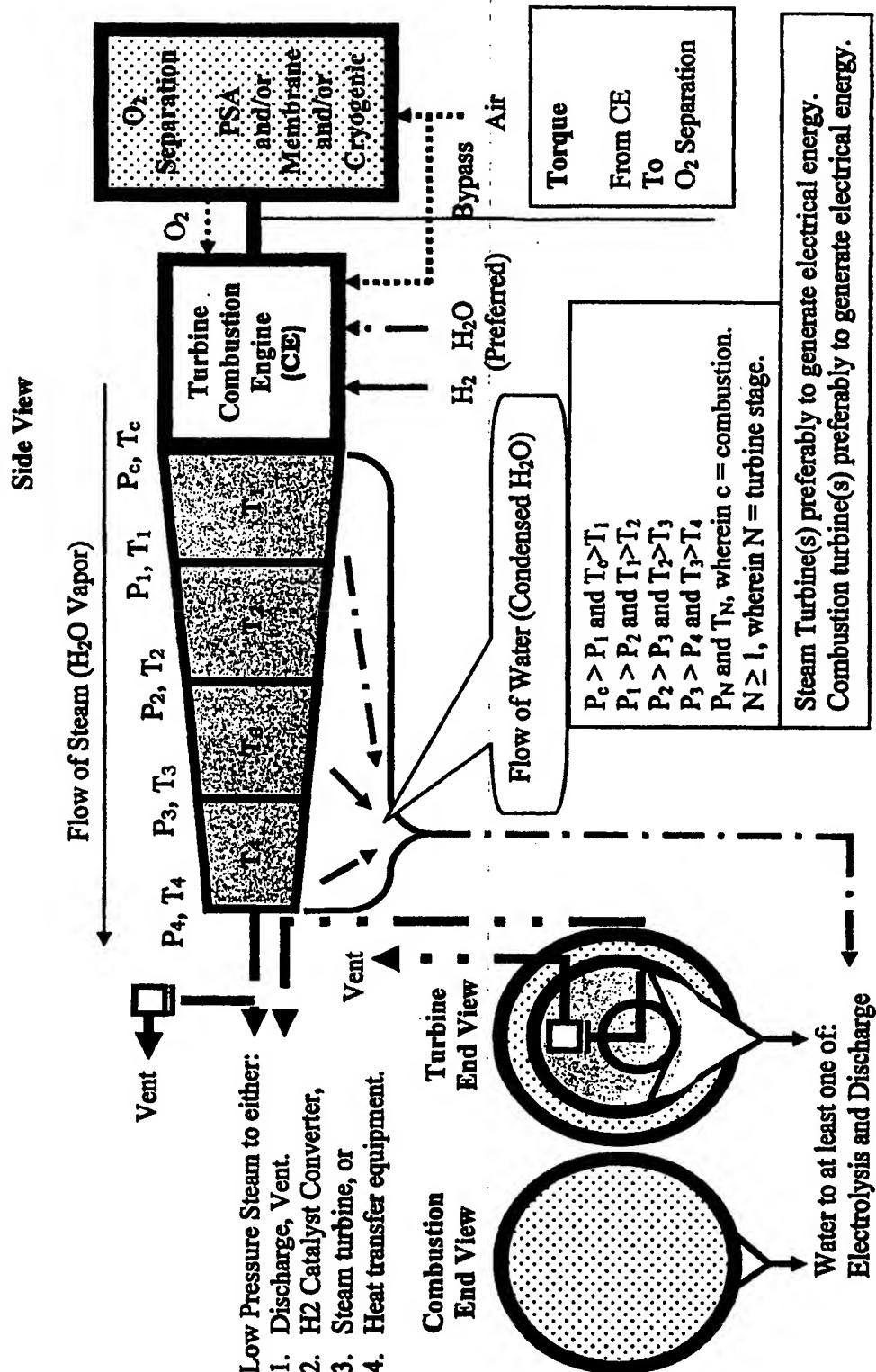


Figure 22
Air Movement Turbine Configuration(s)

$V_1 > V_2$, or $V_1 = V_2$

It is preferred that $V_1 > V_2$

$n = 1, 2, 3, \dots, \infty$

n is satisfied as V_2 approaches 0 or the economics of the next n do not justify the expense or for transportation application, the drag force is too high (such would not be the case for a sail boat).

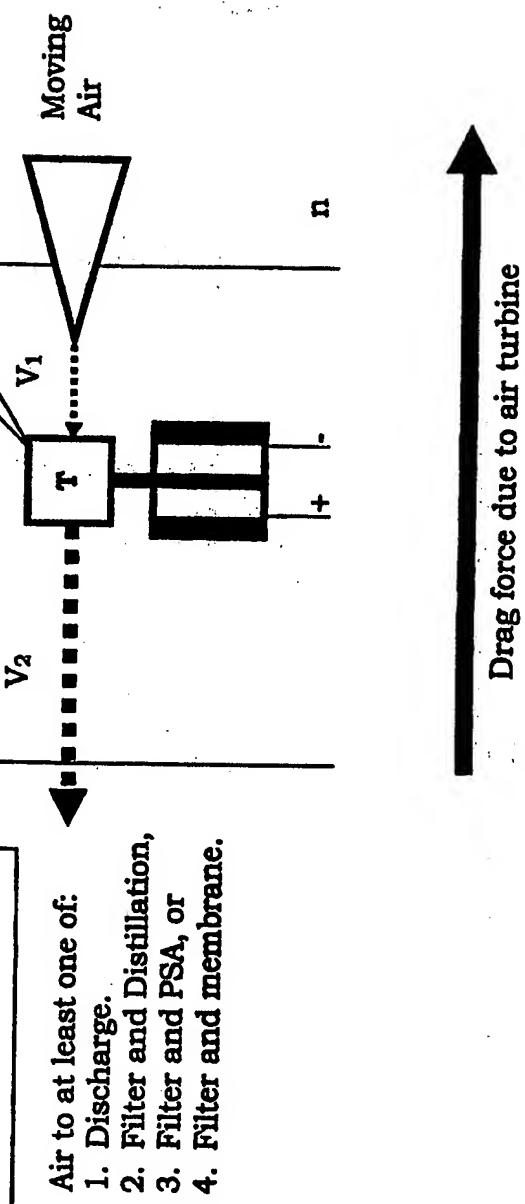


Figure 23
Horizontal Water Movement Turbine Configuration(s)

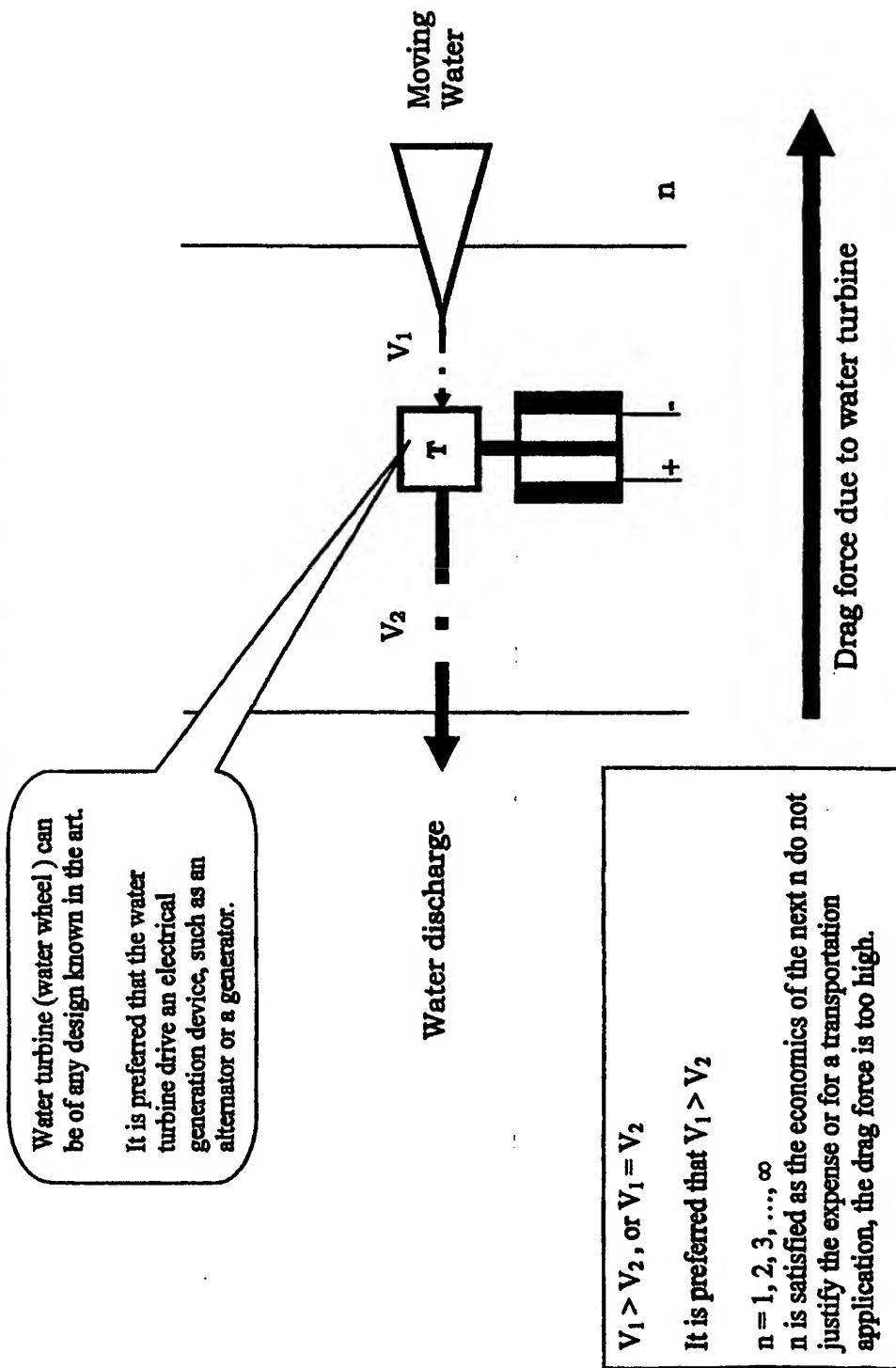


Figure 23A
Vertical Water Movement Turbine Configuration(s)

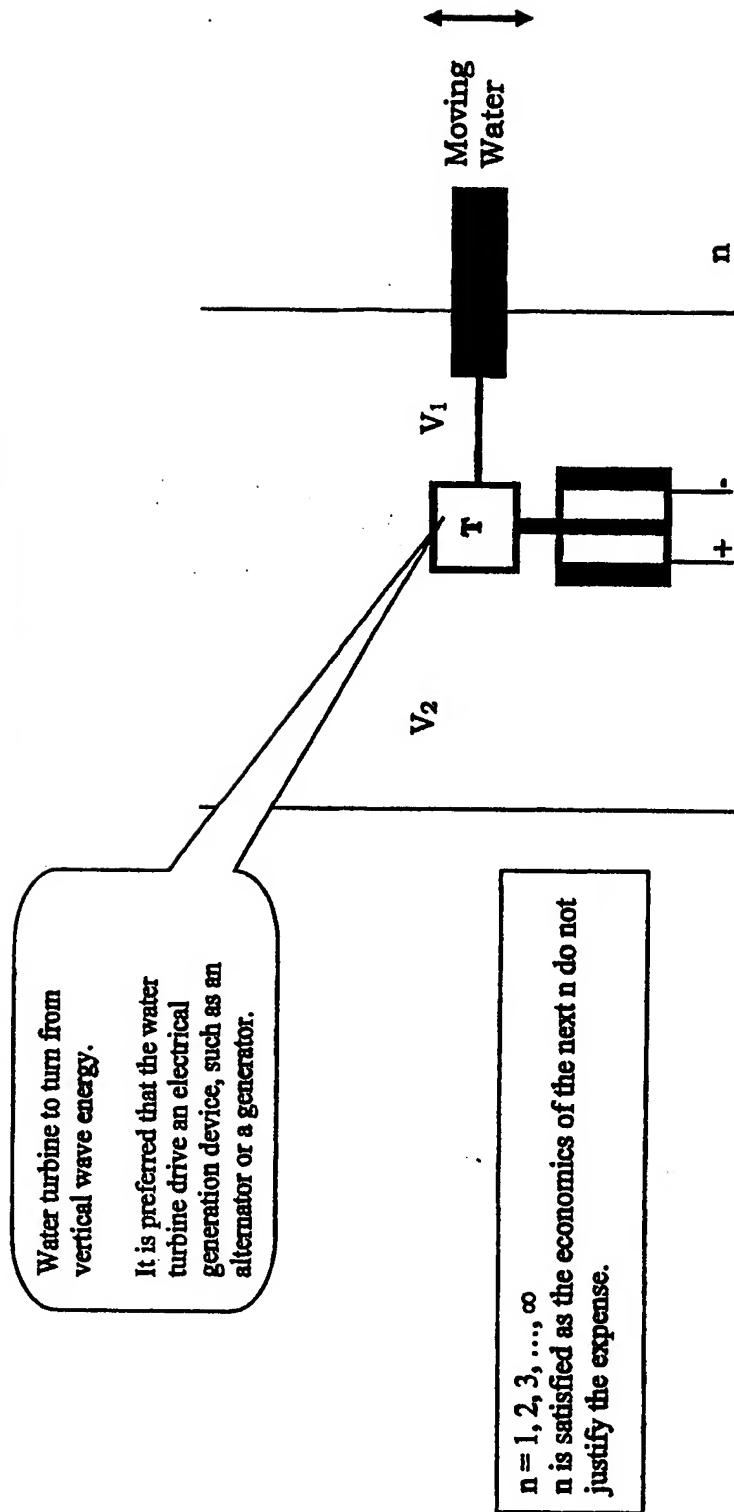
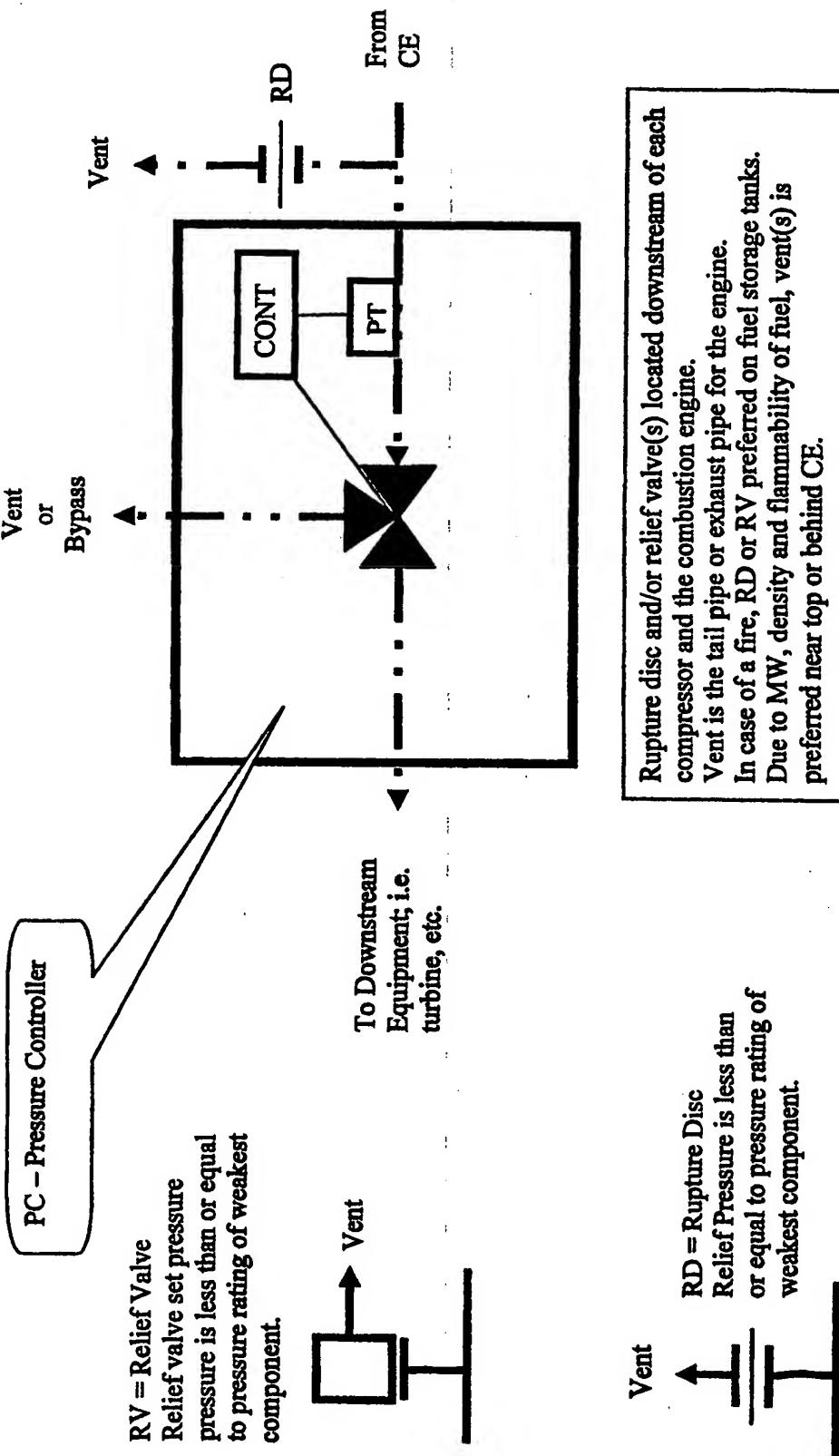


Figure 24
Pressure Control Configuration(s)



PATENT SPECIFICATION

5 TITLE: WATER COMBUSTION TECHNOLOGY - METHODS,
 PROCESSES, SYSTEMS AND APPARATUS FOR THE
 COMBUSTION OF HYDROGEN AND OXYGEN

10 INVENTOR: RICHARD A. HAASE

10 RELATED APPLICATION DATA

This application claims priority of U.S. Provisional Patent Application Serial No. 60/371,768 filed 4/11/02 and of U.S. Provisional Patent Application Serial No. 60/379,587 filed 05/10/02 and of U.S. Provisional Patent Application Serial No. 15 60/404,644 filed 08/19/02 and of U.S. Provisional Patent Application Serial No. 60/447,880 filed 02/14/03.

20 BACKGROUND OF THE INVENTION

20 Field of the Invention

This invention relates to improved combustion methods, processes, systems and apparatus, which provide environmentally friendly combustion products, as well as to fuel and energy management methods, processes, systems and apparatus for said improved combustion methods, processes, systems and apparatus. The combustion and/or fuel and/or energy management methods, processes, systems or apparatus (Water Combustion Technology, WCT) in this invention is based upon the chemistry of Water (H_2O) incorporating Hydrogen and Oxygen, as well as H_2O as fuel. The WCT described in this invention does not use a hydrocarbon as a fuel source, rather the WCT uses H_2 in combination with O_2 . The primary product of the combustion of H_2 and O_2 is H_2O . Further, WCT separates H_2O into H_2 and O_2 , thereby making H_2O an efficient method of storing fuel.

As used herein, the term combustion can incorporate any combustion method, system, process or apparatus, such a furnace, a combustion engine, an internal combustion engine, a turbine or any combustion system wherein mechanical, electrical or heat energy is created. The discovered WCT relate to improved combustion systems

wherein nitrogen (N₂) or N₂ and Argon (Ar) is partially or totally removed from the fuel mixture to improve the energy output of combustion and/or reduce the pollution output of combustion.

The discovered WCT relate to improved methods, processes, systems and apparatus for combustion that significantly improve the thermodynamics of combustion, thereby significantly improving the efficiency of combustion. Further, the discovered WCT relate to improved methods, processes, systems and apparatus for combustion wherein H₂O is added to the fuel mixture to control the combustion temperature, thereby utilizing H₂O during combustion as a heat sink. The steam produced by combustion and/or the cooling of combustion, maintains: 1) the power output of combustion, 2) provides method(s) of energy recycle and 3) provides an efficient method of energy storage, while 4) controlling the combustion temperature, thereby cooling the engine. Steam presents a reusable energy source in the exhaust, both from the available kinetic and the available heat energy, as well as the conversion of said steam into H₂ and/or O₂.

Incorporating H₂O into the fuel mixture with the intent of minimizing or excluding N₂, or N₂ and Ar from the fuel mixture culminates in a fuel mixture that is/are at least one of: O₂, H₂ and H₂O; O₂, H₂, H₂O and N₂; O₂, H₂, H₂O, N₂ and Ar; O₂, H₂, H₂O and air; and H₂, H₂O and air. As used herein, the fuel mixture in the WCT is defined to incorporate either: O₂ and H₂; O₂, H₂ and N₂; O₂, H₂ and Ar; O₂, H₂ and air; O₂, H₂ and H₂O; O₂, H₂, H₂O and N₂; H₂, H₂O, N₂ and Ar; O₂, H₂, H₂O and air; or H₂, H₂O and air.

The discovered WCT relate to methods, processes, systems and apparatus of generating electricity. Four methods, processes, systems and apparatus of generating electricity are discovered. The first places a steam turbine in the exhaust of the combustion engine, wherein said steam turbine is driven by said steam produced in combustion; said steam turbine turning a generator (the term generator is used herein to define either an alternator or a dynamo), wherein at least a portion of said steam energy is converted into said electrical energy. The second places a generator on the mechanical output of a combustion engine, wherein mechanical energy is created, wherein at least a portion of said mechanical energy is converted by said generator into electrical energy. The third, incorporates a physical system of focusing air and/or water currents onto a turbine, wherein said turbine is driven by said moving air or water, wherein said turbine

drives a generator to create electrical energy. The fourth, uses a photovoltaic cell to create electrical energy.

It is discovered to use at least a portion of said electrical energy for the electrolytic generation of H₂O into O₂ and H₂. If a dynamo is used, at least a portion of the dynamo

5 D/C current is used for electrolysis; if an alternator is used an A/C to D/C converter converts at least a portion of the alternating current into direct current for electrolysis. It is further discovered to utilize at least one of said electrolysis generated O₂ and/or H₂ as fuel in the WCT.

The discovered WCT further relate to methods, processes, systems and apparatus 10 for separating O₂ from air. Three are discovered. By the first, O₂ is separated utilizing energy available from said WCT to power a cryogenic distillation system, wherein air is chilled and distilled into O₂ and N₂. By the second, air is separated producing O₂ utilizing membranes; said membranes can be of either organic (polymer) construction or of inorganic (ceramic) construction. By the third, air is separated producing O₂ utilizing 15 Pressure Swing Adsorption (PSA). While the separation of air into O₂ and N₂ can have many degrees of separation efficiency, it is to be understood that the term O₂ as used herein is to mean at least enriched O₂, wherein the O₂ concentration is at least 40 percent; preferably pure O₂, wherein the O₂ concentration is at least 80 percent; and most preferably very pure O₂, wherein the O₂ concentration is at least 90 percent.

20 The discovered WCT further relate to methods, processes, systems and apparatus of metal catalysis, wherein said steam produced in the WCT is converted into H₂ and metal oxides, as part of a catalyst system. It is further discovered that at least a portion of said H₂ be used as a fuel in the WCT. As used herein, the term metal catalysis is to mean any metal or combination of metals in the periodic table, wherein the metal or 25 combination of metals will convert the H₂O within steam or water vapor into the corresponding metal oxide(s) and H₂.

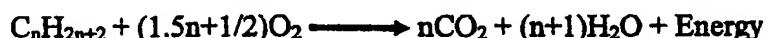
Background and Description of the Prior Art

30 Mankind, has over the centuries, provided many forms of energy and many forms of transportation. In the modern capitalistic economy, the availability of energy is important to literally "fuel" the economic engine, which heats homes, provides electricity, powers lights, powers transportation and powers manufacturing facilities, etc. The

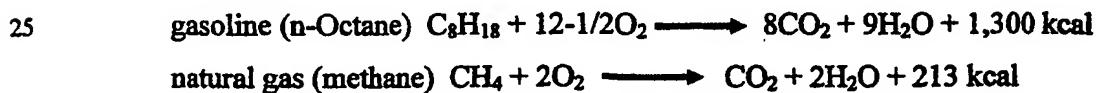
availability of energy is especially important in the transportation of goods and people. During the 19th and 20th centuries mankind developed fossil fuels into reliable and inexpensive fuels for many uses including transportation, powering factories, generating electricity and generating heat. During the 20th century, the use of fossil fuels increased 5 to such an extent as to cause the combustion products of fossil fuels to be a major source of air and water pollution.

It must be understood and appreciated that most fossil fuel combustion systems have an efficiency that is less than 40 percent and that the internal combustion engine has an efficiency of less than 20 percent. These very poor results are a direct consequence of 10 the thermodynamics of combustion. Current combustion systems significantly increase entropy, releasing entropy as well as enthalpy, to their surroundings. This is because it is very difficult for fossil fuel combustion systems to manage temperature without significant entropy and enthalpy losses to their environment; these losses are exhibited as exhaust gases and heat losses to the environment. In summary, the first and second laws 15 of thermodynamics are a liability to fossil fuel combustion systems.

Hydrocarbon(s) have been used in combination with air as fuel for combustion. The hydrocarbons utilized have been petroleum distillates such as gasoline, diesel, fuel oil, jet fuel and kerosene, or fermentation distillates such as methanol and ethanol, or naturally occurring substances such as methane, ethane, propane, butane, coal and wood. 20 The combustion of fossil fuel(s) does not work in concert with nature. The products of fossil fuels were thought to work in concert with nature's oxygen-carbon cycle.



More specifically:



Oxides of carbon (CO_x, CO and/or CO₂) are produced by the combustion of fossil fuels. This production in combination with significant deforestation has left plant life 30 incapable of converting enough of the manmade CO₂ back into O₂. CO, an incomplete combustion by-product, is toxic to all human, animal and plant life. Further, global warming is a result of a buildup of CO_x in the Earth's atmosphere. In addition, the

combustion of air creates oxides of Nitrogen (N), converting a portion of the N₂ to NO_x (NO, NO₂ and/or NO₃). NO_x is toxic to all human, animal and plant life. NO_x is known to inhibit photosynthesis, which is nature's biochemical pathway of converting CO₂ back into O₂. The formation of NO_x is endothermic, thereby lessening combustion efficiency.

5 Further, NO_x reacts with O₂ in the atmosphere to produce ozone (O₃). O₃ is toxic to all human, animal and plant life. O₃ should only exist in higher levels of the atmosphere, wherein O₃ is naturally created from O₂. In the higher levels of the atmosphere O₃ protects all human, animal and plant life from the harmful rays of the sun. Liquid and solid fossil fuels naturally contain sulfur (S) as a contaminant. In combustion, S is

10 oxidized to SO_x (SO₂, SO₃ and/or SO₄). SO_x is toxic to all human, animal and plant life. Lastly, CO_x, NO_x and SO_x react with water in the air to form acids of CO_x, NO_x and/or SO_x, which literally rain acids upon the earth. In summary, CO_x, NO_x, SO_x or O₃ in the air adversely affect the health of all human, animal and plant life. An environmentally acceptable alternative to fossil fuels would be a fuel system that does work in concert

15 with nature. Such a system would not produce CO_x, NO_x or SO_x.

There has been much done mechanically and chemically to combat the environmental issues associated with hydrocarbon combustion. As an example, industrial facilities are outfitted with expensive scrubber systems whenever the politics demand the installation and/or the business supports the installation. As another example, the internal combustion engine has been enhanced significantly to make the engine more fuel efficient and environmentally friendly. Even with enhancement, the internal combustion engine is only approximately 20 percent efficient and the gas turbine/steam turbine system is only approximately 30 to 40 percent efficient. As depicted in Figure 2, the internal combustion engine loses as a percentage of available energy fuel value: 1) approximately 35 percent in the exhaust, 2) approximately 35 percent in cooling, 3) approximately 9 percent in friction losses and 4) only 1 percent due to poor combustion performance, leaving the engine approximately 20 percent efficient.

Hydrocarbon fuels have been modified with additives to minimize the formation of either CO_x or NO_x. However, with all of the scrubber modifications, engine modifications and fuel modifications, the Earth is struggling to deal with manmade pollutants that originate from hydrocarbon combustion systems. In addition to the

environmental issues, availability and dependability of large quantities of petroleum hydrocarbons has become a geopolitical issue.

There have been many previous attempts to produce a combustion engine that would operate on air and H₂. Those attempts had as difficulties: the high temperature of combustion, increased NO_x formation at higher combustion temperatures, storage capacity for large enough quantities of H₂ and cost of operation. The combustion of O₂ and H₂ occurs at over 1100°C (2000°F) making the traditional materials of construction for combustion engines useless. H₂ is a gas at atmospheric pressure. H₂ is not a liquid until the temperature is lowered to near -255°C (-430°F); therefore, storage equipment for H₂ need to either be able to withstand high pressure, cryogenic temperatures or both. Such storage equipment for large volumes of H₂ becomes economically impractical.

Historically and currently it has been believed that the electric motor is the solution to finding an environmentally friendly energy source. However, this concept has deficiencies in that the electrical energy required to power an electric motor must be created and stored. Electrical energy is created with either: 1) hydrocarbon combustion/steam generation processes, 2) photovoltaic generation processes, 3) water driven generation processes, 4) windmill driven generation processes or 5) nuclear generation/steam driven generation processes. While the photovoltaic process is environmentally friendly, the photovoltaic process is not reliable or effective enough in many applications to replace the combustion engine. While the water driven (water wheel) generation process is environmentally friendly, the water driven generation process is a geographically limited energy source. While the windmill driven generation process is environmentally friendly, wind is a limited non-reliable resource. While the nuclear generation/steam driven generation process is environmentally friendly, concerns over the safety of such installations have limited application.

Commercialization of the electric car has been limited due to electrical energy cost and storage of electrical energy so massive that under the best of circumstances the electric car must either be limited to short distances or supplemented with an internal combustion engine.

Previous and current attempts to produce a fuel cell that would operate on H₂ and air, as well as hydrocarbons and air are showing promising results. However, the capital investment to power output ratio for fuel cells is 400 to 500 percent of that same

investment for traditional combustion systems. In addition, in transportation the fuel cell does not have the same "feel" as the internal combustion engine, which may lead to acceptance issues for fuel cells. Previous attempts to replace or reduce the power of the internal combustion engine have failed due to market acceptance. Auto enthusiasts have 5 come to enjoy and expect the "feel" and power of the internal combustion engine.

Previous work to develop a combustion engine that would operate on fuel(s) other than hydrocarbon(s) can be referenced in US 3,884,262, US 3,982,878, US 4,167,919, US 4,308,844, US 4,599,865 US 5,775,091, US 5,293,857, US 5,782,081, US 5,775,091 and US 6,290,184. While each of these patents present improvements in combustion 10 technology, each leaves issues that have left the commercialization of such a combustion engine impractical.

While there are many methods to prepare O_2 , the separation of air into its component gases is industrially performed by three methods: cryogenic distillation, membrane separation and PSA.

15 There are many methods and processes utilized for cryogenic refrigeration, which is a component of cryogenic distillation. A good reference of cryogenic refrigeration methods and processes known in the art would be "Cryogenic Engineering," written by Thomas M. Flynn and printed by Dekker. As written by Flynn, cryogenic refrigeration and liquefaction are the same processes, except liquefaction takes off a portion of the 20 refrigerated liquid which must be made up, wherein refrigeration all of the liquid is recycled. All of the methods and processes of refrigeration and liquefaction are based upon the same basic refrigeration principals, as depicted in Figure 1.

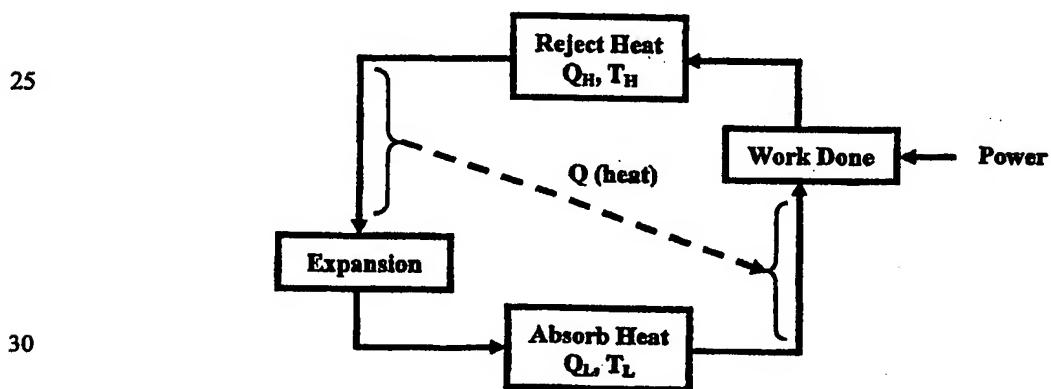


Figure 1

As written by Flynn, there are many ways to combine the few components of work (compression), rejecting heat, expansion and absorbing heat. There exist in the art many methods and processes of cryogenic refrigeration, all of which can be adapted for cryogenic liquefaction. A listing of those refrigeration cycles would include: Joule 5 Thompson, Stirling, Brayton, Claude, Linde, Hampson, Postle, Ericsson, Gifford-McMahon and Vuilleumier. As written by Flynn, "There are as many ways to combine these few components as there are engineers to combine them." (It is important to note, as is known in the art, that H₂ has a negative Joule-Thompson coefficient until temperatures of approximately 350 R are obtained.)

10 Conventional cryogenic air distillation processes that separate air into O₂, Ar and N₂ are commonly based on a dual pressure cycle. Air is first compressed and subsequently cooled. Cooling may be accomplished by one of four methods: 1- Vaporization of a liquid, 2- The Joule Thompson Effect (which performs best when augmented with method 3), 3- Counter-current heat exchange with previously cooled 15 warming product streams or with externally cooled warming product streams and 4- The expansion of a gas in an engine doing external work. The cooled and compressed air is usually introduced into two fractionating zones. The first fractionating zone is thermally linked with a second fractionating zone which is at a lower pressure. The two zones are thermally linked such that a condenser of the first zone reboils the second zone. The air 20 undergoes a partial distillation in the first zone producing a substantially pure N₂ fraction and a liquid fraction that is enriched in O₂. The enriched O₂ fraction is an intermediate feed to the second fractionating zone. The substantially pure liquid N₂ from the first fractionating zone is used as reflux at the top of the second fractionating zone. In the second fractionating zone separation is completed, producing substantially pure O₂ from 25 the bottom of the zone and substantially pure N₂ from the top. When Ar is produced in the conventional process, a third fractionating zone is employed. The feed to this zone is a vapor fraction enriched in Ar which is withdrawn from an intermediate point in the second fractionating zone. The pressure of this third zone is of the same order as that of the second zone. In the third fractionating zone, the feed is rectified into an Ar rich stream 30 which is withdrawn from the top, and a liquid stream which is withdrawn from the bottom of the third fractionating zone and introduced to the second fractionating zone at an intermediate point. Reflux for the third fractionating zone is provided by a condenser

which is located at the top. In this condenser, Ar enriched vapor is condensed by heat exchange from another stream, which is typically the enriched O₂ fraction from the first fractionating zone. The enriched O₂ stream then enters the second fractionating zone in a partially vaporized state at an intermediate point, above the point where the feed to third fractionating zone is withdrawn.

The distillation of air, a ternary mixture, into N₂, O₂ and Ar may be viewed as two binary distillations. One binary distillation is the separation of the high boiling point O₂ from the intermediate boiling point Ar. The other binary distillation is the separation of the intermediate boiling point Ar from the low boiling point N₂. Of these two binary distillations, the former is more difficult, requiring more reflux and/or theoretical trays than the latter. Ar-O₂ separation is the primary function of third fractionating zone and the bottom section of the second fractionating zone below the point where the feed to the third zone is withdrawn. N₂-Ar separation is the primary function of the upper section of the second fractionating zone above the point where the feed to the third fractionating zone is withdrawn.

The ease of distillation is also a function of pressure. Both binary separations become more difficult at higher pressure. This fact dictates that for the conventional arrangement the optimal operating pressure of the second and third fractionating zones is at or near the minimal pressure of one atmosphere. For the conventional arrangement, product recoveries decrease substantially as the operating pressure is increased above one atmosphere mainly due to the increasing difficulty of the Ar-O₂ separation. There are other considerations, however, which make elevated pressure processing attractive. Distillation column diameters and heat exchanger cross sectional areas can be decreased due to increased vapor density. Elevated pressure products can provide substantial compression equipment capital cost savings. In some cases, integration of the air separation process with a power generating gas turbine is desired. In these cases, elevated pressure operation of the air separation process is required. The air feed to the first fractionating zone is at an elevated pressure of approximately 1.01 to 2.02×10^6 Pa (10 to 20 atmospheres) absolute. This causes the operating pressure of the second and third fractionating zones to be approximately 3.04 to 6.08×10^6 Pa (3 to 6 atmospheres) absolute. Operation of the conventional arrangement at these pressures results in very poor product recoveries due to the previously described effect of pressure on the ease of separation.

As used herein: the term "indirect heat exchange" means the bringing of two fluid streams into heat exchange relation without any physical contact or intermixing of the fluids with each other; the term "air" means a mixture comprising primarily N₂, O₂ and Ar; the terms "upper portion" and "lower portion" mean those sections of a column respectively above and below the midpoint of the column; the term "tray" means a contacting stage, which is not necessarily an equilibrium stage, and may mean other contacting apparatus such as packing having a separation capability equivalent to one tray; the term "equilibrium stage" means a vapor-liquid contacting stage whereby the vapor and liquid leaving the stage are in mass transfer equilibrium, e.g. a tray having 100 percent efficiency or a packing element height equivalent to one theoretical plate (HETP); the term "top condenser" means a heat exchange device which generates column downflow liquid from column top vapor; the term "bottom reboiler" means a heat exchange device which generates column upflow vapor from column bottom liquid. (A bottom reboiler may be physically within or outside a column. When the bottom reboiler is within a column, the bottom reboiler encompasses the portion of the column below the lowermost tray or equilibrium stage of the column.)

While it is well known in the chemical industry that the cryogenic distillation of air into O₂ and N₂ is the most economical pathway to produce these elemental diatomic gases, it has not been proposed to utilize this industrial process to either: distill H₂ along with O₂ and N₂, fuel the combustion of O₂ with H₂ or utilize the energy of the combustion of O₂ with H₂ to power the cryogenic distillation of air. Previous work performed to separate air into its components can be referenced in US 4,112,875; US 5,245,832; US 5,976,273; US 6,048,509; US 6,082,136; US 6,298,668 and US 6,333,445.

It is also well known in many industries to separate air with membranes. Two general types of membranes are known in the art: organic polymer membranes and inorganic membranes. These membrane separation processes are improved by setting up an electric potential across a membrane that has been designed to be electrically conductive. While many of these processes are well known and established, it has not been proposed to utilize either of these process to fuel the combustion of O₂ with H₂ or to utilize the energy of the combustion of O₂ with H₂ to power the separation of air. Previous work performed to separate air into its components with membranes can be referenced in US 5,599,383; US 5,820,654; US 6,277,483; US 6,289,884; US 6,298,664;

US 6,315,814; US 6,321,915; US 6,325,218; US 6,340,381; US 6,357,601; US 6,360,524; US 6,361,582; US 6,361,583 and US 6,372,020.

It is also known to separate air into O₂ and N₂ with PSA. However, it has not been proposed to utilize PSA to fuel the combustion of O₂ with H₂ or to utilize the energy of the combustion of O₂ with H₂ to power PSA separation of air. Previous work performed to separate air into its components with PSA can be referenced in US 3,140,931; US 3,140,932; US 3,140,933; US 3,313,091; US 4,481,018; US 4,557,736; US 4,859,217; US 5,464,467; US 6,183,709 and US 6,284,201.

This invention presents H₂O as a fuel, as well as a combustion product. This invention presents novel energy recycle methods, processes, systems and apparatus to improve the efficiency of combustion by utilizing water as a combustion product, an energy conduit and an energy storage medium. The inherent energy losses incurred in hydrocarbon combustion are unrecoverable; with hydrocarbon combustion there is no practical method of recovering lost exhaust energy, heat energy or mechanical energy.

The discovered WCT relate to chemical methods, processes, systems and apparatus for producing H₂ from steam, since steam is the physical state of the water product from the WCT. Previous work in this field has focused on refinery or power plant exhaust gases; none of that work discusses the separation of H₂O back into H₂. Previous work performed to utilize the products of hydrocarbon combustion from an internal combustion engine can be referenced in US 4,003,343. Previous work in corrosion is in the direction of preventing corrosion instead of encouraging corrosion, yet can be referenced in US 6,315,876, US 6,320,395, US 6,331,243, US 6,346,188, US 6,348,143 and US 6,358,397.

The discovered WCT relate to electrolytic methods, processes, systems and apparatus to chemically convert H₂O into O₂ and H₂. While there have been improvements in the technology of electrolysis and there have been many attempts to incorporate electrolysis with a combustion engine, wherein the hydrocarbon fuel is supplemented by H₂ produced by electrolysis, there has been no work with electrolysis to fuel a combustion engine wherein electrolysis is a significant source of O₂ and H₂. Previous work in electrolysis as electrolysis relate to combustion systems can be referenced in US 6,336,430, US 6,338,786, US 6,361,893, US 6,365,026, US 6,635,032 and US 4,003,035.

The discovered WCT relate to the production of electricity. The mechanical energy for a mechanically driven electrical generation device, which can be a generator, is produced by the fuel(s) of the WCT. In addition, the steam energy for a steam driven generator is produced by the fuel(s) of the WCT. Further, the WCT Engine exhaust steam energy may drive a steam turbine, thereby driving a generator creating an electrical current. Further, said exhaust gas, H_2O , minimizes environmental equipment. The discovered WCT presents a combustion turbine, wherein the exhaust gas is at least primarily if not totally H_2O . While there has been much work in the design of steam turbines, in all cases the steam for the steam turbine is generated by heat transfer, wherein said heat for heat transfer is created by nuclear fission or hydrocarbon combustion. The concept of utilizing a steam turbine in the direct exhaust of a combustion engine or to recycle energy within a combustion engine, especially to create electricity for the electrolytic conversion of H_2O into O_2 and H_2 is new and novel. Previous work in steam turbine generation technology or engine exhaust turbine technology can be referenced in: US 6,100,600, US 6,305,901, US 6,332,754, US 6,341,941, US 6,345,952, US 4,003,035, US 6,298,651, US 6,354,798, US 6,357,235, US 6,358,004 and US 6,363,710.

The discovered WCT relate to air and water driven turbine technologies to create electricity. Air or water driven turbine electrical generation technology would be applicable to combustion system(s) utilizing the discovered WCT, wherein: there is a reliable source of moving air and/or water. While a moving source of air or a moving source of water may be an excellent source of electrical power generation to fuel the electrolysis of H_2O , the concept of either: the use of said electrolysis to fuel the discovered WCT or of a windmill or waterwheel to power said electrolysis in order to fuel the discovered WCT is novel. Previous work in wind driven generator technology can be referenced in US 3,995,972, US 4,024,409, US 5,709,419, US 6,132,172, US 6,153,944, US 6,224,338, US 6,232,673, US 6,239,506, US 6,247,897, US 6,270,308, US 6,273,680, US 293,835, US 294,844, US 6,302,652, US 6,323,572, and US 6,635,981.

The discovered WCT relate to photovoltaic methods, processes, systems and apparatus to create electricity, wherein said electricity is used to create at least one of H_2 and O_2 , wherein said H_2 and/or said O_2 is used as a fuel in said WCT. There are many methods, processes, systems and apparatus for the photovoltaic production of electricity, as is known in the art. There are many methods, systems and processes wherein a

photovoltaic cell is used to create electricity for the electrolytic separation of H₂O into H₂ and O₂, wherein the H₂ is used in a fuel cell. Previous work in photovoltaic cells in relation to the production of H₂ can be referenced in: US 5,797,997, US 5,900,330, US 5,986,206, US 6,075,203, US 6,128,903, US 6,166,397, US 6,172,296, US 6,211,643, US 5 6,214,636, US 6,279,321, US 6,372,978, US 6,459,231, US 6,471,834, US 6,489, 553, US 6,503,648, US 6,508,929, US 6,515,219 and US 6,515,283. None of the previous work describes or suggests the use of a photovoltaic cell in combination with said WCT.

The discovered WCT relate to methods of controlling corrosion, scale and deposition in water applications. U.S. Patent No. 4,209,398 issued to Ii, et al., on June 10 1980 presents a process for treating water to inhibit formation of scale and deposits on surfaces in contact with the water and to minimize corrosion of the surfaces. The process comprises mixing in the water an effective amount of water soluble polymer containing a structural unit that is derived from a monomer having an ethylenically unsaturated bond and having one or more carboxyl radicals, at least a part of said 15 carboxyl radicals being modified, and one or more corrosion inhibitor compounds selected from the group consisting of inorganic phosphoric acids and water soluble salts therefore, phosphonic acids and water soluble salts thereof, organic phosphoric acids and water soluble salts thereof, organic phosphoric acid esters and water -soluble salts thereof and polyvalent metal salts, capable of being dissociated to polyvalent metal ions in water. 20 The Ii patent does not discuss or present systems of electrolysis or of combustion.

U.S. Patent No. 4,442,009 issued to O'Leary, et al., on April 10, 1984 presents a method for controlling scale formed from water soluble calcium, magnesium and iron impurities contained in boiler water. The method comprises adding to the water a chelant and water soluble salts thereof, a water soluble phosphate salt and a water soluble poly 25 methacrylic acid or water soluble salt thereof. The O'Leary patent does not discuss or present systems of electrolysis or of combustion.

U.S. Patent No. 4,631,131 issued to Cuisia, et al., on December 23, 1986 presents a method for inhibiting formation of scale in an aqueous steam generating boiler system. Said method comprises a chemical treatment consisting essentially of adding to the water 30 in the boiler system scale-inhibiting amounts of a composition comprising a copolymer of maleic acid and alkyl sulfonic acid or a water soluble salt thereof, hydroxyl ethylenel, 1-diphosphic acid or a water soluble salt thereof and a water soluble sodium phosphate

hardness precipitating agent. The Cuisia patent does not discuss or present systems of electrolysis or of combustion.

U.S. Patent No. 4,640,793 issued to Persinski, et al., on February 3, 1987 presents an admixture, and its use in inhibiting scale and corrosion in aqueous systems, 5 comprising: (a) a water soluble polymer having a weight average molecular weight of less than 25,000 comprising an unsaturated carboxylic acid and an unsaturated sulfonic acid, or their salts, having a ratio of 1:20 to 20:1, and (b) at least one compound selected from the group consisting of water soluble polycarboxylates, phosphonates, phosphates, polyphosphates, metal salts and sulfonates. The Persinski patent presents chemical 10 combinations which prevent scale and corrosion; however, the Persinski patent does not address electrolysis or combustion.

SUMMARY OF THE INVENTION

15 A primary object of the invention is to devise environmentally friendly, effective, efficient and economically feasible combustion methods, processes, systems and apparatus.

20 Another object of the invention is to devise environmentally friendly, effective, efficient and economically feasible combustion methods, processes, systems and apparatus for an internal combustion engine.

Another object of the invention is to devise environmentally friendly, effective, efficient and economically feasible combustion methods, processes, systems and apparatus for electrical energy generation.

25 Another object of the invention is to devise effective, efficient and economically feasible combustion methods, processes, systems and apparatus that do not produce oxides of carbon.

Another object of the invention is to devise effective, efficient and economically feasible combustion methods, processes, systems and apparatus that minimize the production of oxides of nitrogen.

30 Another object of the invention is to devise effective, efficient and economically feasible fuel system for an environmentally friendly, effective and efficient combustion methods, processes, systems and apparatus.

Another object of the invention is to devise effective, efficient and economically feasible fuel methods, processes, systems and apparatus for environmentally friendly, effective and efficient internal combustion engines.

5 Another object of the invention is to devise effective, efficient and economically feasible fuel methods, processes, systems and apparatus for environmentally friendly, effective and efficient electricity production.

Another object of the invention is to devise effective, efficient and economically feasible fuel methods, processes, systems and apparatus for environmentally friendly, effective and efficient heat generation.

10 Another object of the invention is to devise effective, efficient and economically feasible combustion methods, processes, systems and apparatus that includes hydrogen and oxygen or hydrogen and air or hydrogen and oxygen and air, wherein the temperature of combustion is controlled by the addition of water to combustion so that economical materials of construction for a combustion engine can be used.

15 Another object of the invention is to devise effective, efficient and economically feasible methods, processes, systems and apparatus of increasing the efficiency of combustion.

20 Another object of the invention is to devise effective, efficient and economically feasible electrolytic methods, processes, systems and apparatus to convert water into oxygen and/or hydrogen utilizing the energy available from combustion.

25 Another object of the invention is to devise effective, efficient and economically feasible catalytic methods, processes, systems and apparatus for the conversion of steam into hydrogen, wherein the steam is produced by a combustion engine that is fueled by at least one of: oxygen, hydrogen and water; oxygen, hydrogen, water and nitrogen; oxygen, hydrogen, water and air; hydrogen, water and air.

Additional objects and advantages of the invention will be set forth in part in a description which follows and in part will be obvious from the description, or may be learned by practice of the invention.

30 An improved environmentally friendly process to create energy over that of the combustion of fossil fuels would be a process that does not produce a product of which the earth would have to naturally remove or convert. This invention specified in the claims, VCT, presents a product which could perform such a task, namely H₂O. Water is made by the combustion

of O₂ and H₂. Further, known methods to produce O₂ are by: liquefaction (cryogenic distillation) of air; membrane separation of air, Pressure Swing Adsorption (PSA) of air and electrolysis of H₂O. All of these processes are friendly to the environment. In addition, H₂ is the most abundant element in the universe existing in nearly all compounds and compositions. Modifying our alcohol, oil, coal and gas refineries to produce H₂ would stimulate economic expansion, while focusing the responsibility of air pollution into a refining environment, wherein that responsibility can be managed.

5 The discovered WCT manages energy much more efficiently than that of the traditional combustion engine, as the traditional combustion engine relates to transportation, electricity generation and heat generation applications. This is especially the case with respect to the internal combustion engine. The internal combustion engine, as well as combustion engines generally, loose approximately 60 to 85 percent of their combustion energy in: heat losses from the engine, engine exhaust gases and unused mechanical energy. This invention recaptures significant portions of energy loss by 10 converting lost energy into electrical energy which is converted into chemical potential 15 energy.

10 The discovered WCT utilizes the energy of combustion of O₂ with H₂ as the energy source for combustion methods, processes, systems and apparatus to create energy. The combustion product of O₂ and H₂ is H₂O. This combustion reaction is somewhat similar 15 to that of hydrocarbon combustion; however, carbon is removed from the reaction and N₂ is partially or totally removed from the reaction. In summary, the WCT eliminates the 20 environmental issues associated with the combustion of C, N and/or S.



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At 68.5 kcal/mole, H₂ has an energy value of 75 cal g⁻¹ (34 kcal per pound), this compared favorably to n-Octane which is 1300 kcal/mole = 24 cal g⁻¹ (11 kcal per pound) and methane which is 213 kcal/mole = 29 cal g⁻¹ (13 kcal per pound).

30 While H₂O is an environmentally friendly combustion product, the combustion temperature of O₂ with H₂ is too high for most combustion system materials. And, especially in the case of the internal combustion engine, the implementation of any new combustion system would be significantly facilitated through the use of traditional

materials of construction, so as to minimize the cost of engine construction. This invention utilizes H₂O as a preferred embodiment to control the combustion temperature of O₂ with H₂. Said H₂O can be in one of three forms: a solid (ice particles), a liquid (water vapor) and a gas (steam). If H₂O is in the form of a solid, the combustion 5 temperature will be controlled by: the heat capacity of solid H₂O, the sublimation energy of H₂O, the heat capacity of H₂O vapor, the latent heat of vaporization of H₂O and the heat capacity of steam. If H₂O is in the form of a liquid, the combustion temperature will be controlled by: the heat capacity of liquid H₂O, the latent heat of vaporization of H₂O and the heat capacity of steam. If the H₂O is a gas, the temperature will be controlled by 10 the heat capacity of steam.

While traditionally, air has been used as the combustion oxidant (O₂ in air), combustion of O₂ with H₂, without the inclusion of N₂ and/or Ar or with a minimal inclusion of N₂ and/or Ar from air, improves combustion energy output by over 300 percent. This aspect of the instant invention can be readily seen by comparing a 15 combustion system which utilizes air for the oxidant, wherein air is approximately only 20 percent O₂ and 78 percent N₂, and a combustion system which utilizes very pure O₂ as the oxidant. Nitrogen reduces the combustion temperature while endothermically producing NO_x, thereby creating pollution while reducing engine efficiency. Since air is approximately 78 percent N₂, nearly 78 percent of the combustion mixture in a traditional 20 combustion engine provides no energy during combustion, and in actuality, reduces the energy output of combustion. While the N₂ in air can keep the combustion temperature down, thereby producing exhaust gas temperatures approximately near or below 1000 °F, so that the combustion temperature is not harmful to traditional materials of engine construction, the addition of H₂O to an O₂/H₂ fuel mixture approaches isothermal 25 combustion producing steam while cooling the temperature of combustion, thereby converting combustion heat energy into an energy form that is easily recycled. The inclusion of N₂ does not provide the ability of energy recycle. The same discussion applies to Ar.

As is readily understood in combustion science, there are three components 30 required for combustion to commence: fuel, heat and ignition. Assuming a constant source of fuel (H₂ and O₂) and ignition, the addition of H₂O to the combustion mixture presents a method and process to: limit the combustion temperature and minimize the

cost of materials of construction for the combustion engine, as well as maintain a high enough combustion temperature so that combustion may commence. The addition of H₂O to the combustion chamber can be managed to maintain combustion, as well as control the temperature of combustion. Varying engine configurations, combustion 5 chamber designs and materials of construction will determine the limits of H₂O addition to the combustion chamber within the limits of combustion temperature.

The discovered WCT presents H₂O as at least one of: an energy storage medium, a combustion product, a coolant and an energy transfer conduit and/or any combination therein. The importance of this aspect of the invention can be appreciated by 10 thermodynamic principals. By the first law of thermodynamics, heat added to the system plus work done on the system equals changes in internal energy plus changes in potential and kinetic energy. The recycling of otherwise lost energy by this invention increases both the internal and potential energy, thereby increasing efficiency of the combustion systems. By the second law of thermodynamics: changes in internal energy equal 15 changes in entropy (at a specific temperature) minus the work performed by the system. Since, the invention significantly reduces changes in entropy by recycling otherwise lost entropy while focusing otherwise lost enthalpy into recycled exhaust enthalpy/entropy, the invention significantly increases the internal energy, thereby significantly increasing efficiency. The WCT uses the first and second laws of thermodynamics as an asset. In 20 contrast, hydrocarbon combustion technology has the first and second laws of thermodynamics as a liability. Further, the use of H₂O in the combustion chamber theoretically approaches isothermal combustion.

This invention utilizes electro-chemical pathways to convert H₂O into O₂ and H₂, wherein the electrical energy for these pathways is obtained from at least one of: cooling 25 the engine, exhaust gas energy, combustion output mechanical energy, photovoltaic energy and the energy of air or water motion. Given that the efficiency of most combustion engines (especially the internal combustion engine) is only approximately 20 percent, the discovered WCT can significantly increase the efficiency of combustion. Assuming that the available H₂ fuel has a conversion efficiency near that of its 30 hydrocarbon predecessors, thereby presenting a source value of 100 percent for fresh H₂ and that the separation of air into O₂, N₂ and Ar has an efficiency of near 20 percent, the methods, processes, systems and apparatus of this invention have the capability to

increase the efficiency of a combustion engine to near 40 to 70 percent and the efficiency of the internal combustion engine to near approximately 50 percent. It is theorized that the combustion efficiency can be increased further, depending on the separation efficiency of air into O₂, N₂ and Ar. It is discovered by this invention that the theoretical 5 limit of efficiency for the discovered WCT is approximately limited to the efficiency limit in the conversion of steam, mechanical, photovoltaic, wind and waterwheel energy to electricity in combination with the efficiency limit of electrolysis to convert H₂O into H₂ and O₂ minus friction losses. This theoretical limit presents that the theoretical efficiency limit of the methods, processes, systems and apparatus of combustion in this invention is 10 near approximately 70-80 percent. (There is an interesting situation, wherein the engine is not running and a photovoltaic cell increases the internal energy by creating fuel from water. Under this scenario the engine actually increases its fuel without using any fuel, wherein the efficiency is infinite.)

15 The discovered WCT present methods, processes, systems and apparatus for separating O₂ and N₂ from air in combination with the combustion of O₂ with H₂. There are three methods of separation. By the first method, air is separated utilizing the cryogenic distillation process, which is used to pressure, chill and distill the air, separating air into O₂ and N₂. By the second method, air is separated utilizing membranes; the membranes can be of either organic polymer construction or of inorganic 20 construction. By the third method, air is separated by utilizing Pressure Swing Adsorption (PSA). Utilizing PSA it is preferred that O₂ be absorbed; however, it is practical that N₂ be absorbed. The separated O₂, produced by at least one of these methods, is preferably used as a fuel in the combustion systems.

25 Cryogenic Distillation – In the chemical industry, cryogenic distillation of air into O₂ and N₂ is a common pathway to produce these elemental diatomic gases. However, it has not been proposed previously and it is novel to utilize this process: in combination with H₂ distillation, to fuel the combustion of O₂ with H₂ and/or to utilize the energy of the combustion of O₂ with H₂ to power the cryogenic distillation of air. In addition, nearly all industrial processes for the separation of air into O₂ and N₂ utilize N₂ or N₂ and 30 Ar as industrial products. In the case of the discovered WCT, the primary use of distilled N₂ and/or Ar would be as a heat sink. This heat sink is preferably utilized to perform at least one of: cool the storage of O₂ or of H₂, facilitate cryogenic distillation, cool the

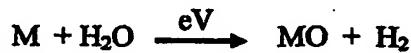
combustion engine and/or provide refrigeration and/or environmental cooling. In the case of the internal combustion engine, this heat sink is preferably used in place of the engine water coolant cooling system (typically a fan cooled radiator) and/or the compressor for the passenger cooling (air conditioning) system. This invention also 5 proposes that the distillation of Ar is immaterial except as a combustion efficiency improvement; the additional fractionating column to separate Ar should be viewed on a capital investment – efficiency rate of return analysis.

10 Membrane Separation – Membrane separation is much simpler than cryogenic distillation; however, nitrogen is not available as a heat sink. By utilizing the membrane separation process, separate cooling systems will need to potentially be available for the engine and for any passenger or environmental cooling.

15 PSA - PSA separation is simpler than cryogenic processes yet more complicated than membrane separation. PSA has the same drawback, as does membrane separation; N₂ would not be available as a heat sink. By utilizing a PSA separation process, separate cooling systems will need to potentially be available for the engine and for any passenger or environmental cooling.

20 The discovered WCT relate to chemical methods, processes, systems and apparatus of producing H₂ from steam, since steam is the physical state of the water product from the combustion. This invention converts steam into H₂ utilizing a process, which is normally considered a detriment. This invention utilizes corrosion to chemically convert steam to H₂. Corrosion utilizes O₂ to convert a metal to its metal oxide, while releasing H₂. This metal oxide has traditionally been viewed as a detriment since the metal oxide has less strength, durability and luster than its metal counterpart. The general chemical reaction for corrosion with water as the oxidant would be:

25



30 where, M is any metal or combination of metals from the Periodic Table and eV is the electromotive potential. Due to the electromotive potential of corrosion, many methods of protecting a metal against corrosion are based upon managing the electromotive potential of the metal. One such method is cathodic protection. Under cathodic protection, the metal is protected against corrosion by producing an electromotive

potential in the metal that is counter to the electromotive potential for corrosion of that metal. Where traditional cathodic protection methods are used to prevent corrosion, this invention proposes driving corrosion by creating an anodic potential. This invention proposes placing catalytic sacrificial metal(s) in the exhaust gas (steam) of the WCT, 5 wherein an anodic potential is preferably used to drive the corrosion of a metal or a composition of metals, thereby converting at least a portion of the steam to hydrogen. (A good reference for electromotive potentials would be the *Handbook of Chemistry and Physics* by CRC Press.)

The discovered WCT relates to electrolytic methods, processes, systems and 10 apparatus to electro-chemically convert H_2O into O_2 and H_2 . It is to be understood that under the best of engineered circumstances, the electrical energy required by electrolysis to convert H_2O into O_2 and H_2 will be greater than the energy obtained by the combustion 15 of O_2 and H_2 . However, electrolysis allows for significant improvements in the efficiency of combustion by reclaiming energy which would otherwise be lost. Whether the electrical energy recovered is from the steam of combustion or from at least one of: 20 mechanical energy conversion, steam energy conversion, light energy conversion, wind energy conversion or water wheel energy conversion, once the capital cost of conversion equipment is in place, the cost of energy conversion is limited to equipment maintenance expense. Four types of available electrical energy conversion are discovered in this invention: mechanical energy, steam energy, moving air (wind) or water energy and photovoltaic (sun) energy.

Electrolysis may create enough fuel from H_2O at a very low energy conversion 25 cost to increase the fuel efficiency of the entire combustion system. The application of the internal combustion engine is an excellent example of a situation wherein electrolysis may be used to turn H_2O into a fuel source. The internal combustion engine, once in operation, turns normally at approximately 500 to approximately 6000 rpm and infrequently in specially engineered situation to approximately 10,000 to 20,000 rpm. There are many situations in the operation of combustion engines wherein a generator 30 either located on the drive shaft or activated by a transmission device and driven by the drive shaft, could be turned by the mechanical energy of the combustion engine to create an electrical current for the electrolytic conversion of H_2O into O_2 and H_2 . In addition, to the extent that H_2O is utilized to control the combustion temperature of the combustion

system is to the extent that a steam driven turbine generator can be further utilized in the exhaust stream of the WCT to create electricity. Electricity can then be used for the electrolysis of H_2O into O_2 and H_2 . In the case of the use of the WCT specifically for the generation of electricity, there would not be much excess electricity. Once the capital 5 cost of either the mechanical driven generator or the steam driven generator has been made, the conversion cost of the mechanical or steam energy to electricity is limited to equipment maintenance expense. This same cost/benefit scenario would apply to a moving air (wind) or water driven generator, as well as to the photovoltaic system.

This invention relates to the application of muffler technologies as those 10 technologies are known and used to muffle the noise of combustion. In the case of the internal combustion engine, mufflers are installed to limit the noise produced by combustion. While muffler designs do control the noise or air vibration from a combustion engine, current muffler designs waste available combustion exhaust gas energy. The installation of a steam turbine in the combustion engine exhaust gas stream 15 is preferred to produce an electrical current. It is preferred that the steam turbine absorb air vibration from combustion. It is preferred to install easily oxidized metal(s) in a contact/muffler chamber to create H_2 from the steam produced in the combustion systems. The combination of a steam driven turbine generator and catalytic conversion metal(s) in 20 the exhaust would be a most preferred combination to convert the steam energy of the exhaust gases from the combustion systems into electrical energy, while muffling the air vibration in the exhaust gases.

Brief Description of the Drawings

A better understanding of the present invention can be obtained when the 25 following description of the preferred embodiments are considered in conjunction with the following drawings, in which:

Tables 1 and 1A provide a key to the symbols of Figures 1 through 15.

Figure 2 illustrates in block diagram from a general thermodynamic description of the traditional hydrocarbon combustion engine.

30 Figure 2A illustrates in block diagram form a general description of proposed methods, processes, systems and apparatus to manage H_2O , O_2 , H_2 and air in the discovered WCT combustion engine.

5 Figure 3 illustrates in block diagram form a general description of proposed methods, processes, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates alternate methods, processes, systems and apparatus to create electricity for electrolysis to convert H₂O into H₂ and O₂.

10 Figure 4 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates catalytic conversion of steam into H₂.

15 Figure 5 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates the cryogenic distillation of air into nitrogen and O₂.

20 Figure 6 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates catalytic conversion of steam into H₂, as well as alternate methods, processes, systems and apparatus to create electricity for electrolysis to convert H₂O into H₂ and O₂.

25 Figure 7 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the combustion temperature and the fuel system incorporates the cryogenic distillation of air into nitrogen and O₂, as well as alternate methods, processes, systems and apparatus to create electricity for electrolysis to convert H₂O into H₂ and O₂.

30 Figure 8 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least

one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates catalytic conversion of steam into H₂, along with the cryogenic distillation of air into nitrogen and O₂, as well as alternate methods, processes, systems and apparatus to 5 create electricity for electrolysis to convert H₂O into H₂ and O₂.

Figure 9 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system 10 incorporates the separation of air into nitrogen and O₂ with at least one of membranes and PSA.

Figure 10 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion 15 chamber and to cool the combustion temperature, and wherein the fuel system incorporates the separation of air into nitrogen and O₂ with at least one of membranes and PSA, as well as alternate methods, processes, systems and apparatus to create electricity for electrolysis to convert H₂O into H₂ and O₂.

Figure 11 illustrates in block diagram form a general description of proposed 20 methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates catalytic conversion of steam into H₂, along with the separation of air into nitrogen and O₂ with at least one of membranes and PSA, as well as alternate methods, 25 processes, systems and apparatus to create electricity for electrolysis to convert H₂O into H₂ and O₂.

Figure 12 illustrates in block diagram form a general description of proposed 30 methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates catalytic conversion of steam into H₂, along with the cryogenic distillation of air into nitrogen and O₂.

Figure 13 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system 5 incorporates catalytic conversion of steam into H₂, along with the separation of air into nitrogen and O₂ with at least one of membranes and PSA.

Figure 14 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for heating the combustion mixture for a combustion engine that is fueled by at least one of: O₂ and H₂, air and H₂, and wherein 10 H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

Figure 15 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion 15 chamber and to cool the combustion temperature, and wherein the fuel system incorporates the cryogenic distillation of air into nitrogen and O₂.

Figure 16 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion 20 chamber and to cool the combustion temperature, and wherein the fuel system incorporates the separation of air into nitrogen and O₂ with at least one of membranes and PSA.

Figure 17 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for a combustion engine fueled by at least 25 one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system incorporates catalytic conversion of steam into H₂, along with the cryogenic distillation of air into nitrogen and O₂.

Figure 18 illustrates in block diagram form a general description of proposed 30 methods, procedures, systems and apparatus for a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature, and wherein the fuel system

incorporates catalytic conversion of steam into H₂, along with the separation of air into nitrogen and O₂ with at least one of membranes and PSA.

Figure 19 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for heating the combustion mixture for a combustion engine that is fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

Figure 20 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for liquefaction and cooling of O₂ and/or H₂ storage for a combustion engine that is fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

Figures 21 and 21A illustrate in block diagram form a general description of proposed methods, procedures, systems and apparatus for a steam turbine, wherein the steam turbine is located in and powered by the exhaust of a combustion engine fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

Figure 22 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for an air turbine, wherein said air turbine provides electricity to separate H₂O into H₂ and O₂ for a combustion engine, wherein said combustion engine is fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

Figures 23 and 23A illustrate in block diagram form a general description of proposed methods, procedures, systems and apparatus for a H₂O turbine, wherein said H₂O turbine provides electricity to separate H₂O into H₂ and O₂ for a combustion engine, wherein said combustion engine is fueled by at least one of: O₂ and H₂, air and H₂, and wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

Figure 24 illustrates in block diagram form a general description of proposed methods, procedures, systems and apparatus for pressure control for a combustion engine, wherein said combustion engine is fueled by at least one of: O₂ and H₂, air and H₂, and

wherein H₂O is an option to cool the combustion chamber and to cool the combustion temperature.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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The timing of the invention is significant since global warming is becoming a global political issue. The timing of the invention is significant since the availability of oil, the primary source of hydrocarbons, is becoming a global political issue. The timing of the invention is significant since air pollution is becoming a health issue for much of 10 humanity. The timing of the invention is significant since the market of natural gas (methane, ethane, propane and/or butane) is affecting the production and/or market price of electricity. This invention presents environmentally friendly combustion methods, processes, systems and apparatus, which are efficient and which will require a reasonable amount of tooling to implement. And, in the case of the internal combustion engine, this 15 invention presents a combustion process, which will have a "feel" to the driver which is similar to that of hydrocarbon combustion engines; this "feel" will further implementation of the invention.

The methods, processes, systems and apparatus of the WCT Engine solve the myriad of challenges that have kept hydrogen based combustion technologies from 20 commercialization. These challenges are, yet are not limited to: 1) fuel combustion temperature and the associated combustion engine cost, 2) the volume of fuel required and the associated fuel storage requirements, 3) engine efficiency and the associated fuel required, 4) the generation of NO_x, 5) engine efficiency and the associated cost of operation, 6) combustion engine size and the associated combustion engine cost, 7) 25 required fuel and fuel storage in general, 8) cost of operation in general, 9) combustion engine cost in general and in the case of the internal combustion engine 10) an engine that meets customer expectations for feel, efficiency, cost and environmental impact.

The methods, processes, systems and apparatus of the WCT utilize the heat of combustion of O₂ with H₂ as the primary energy source for combustion systems to create 30 energy. A preferred embodiment of this invention would be to combust O₂ with H₂. A most preferred embodiment of this invention would be to add H₂O to the combustion chamber to control the combustion temperature. It is an embodiment to cool the engine

with H₂O in the combustion chamber, wherein the gas of combustion is at least one of water vapor and steam. It is a preferred embodiment of WCT to manage the final temperature in the combustion mixture prior to ignition so that the mixture is in at least one of a gaseous or fluid state.

5 Since the storage of O₂ and H₂ would be best accomplished at cryogenic temperatures, cryogenic O₂ and/or cryogenic H₂ may inhibit combustion. A preferred embodiment of this invention would be to at least partially control the combustion temperature and/or the engine temperature by the temperature of cryogenic O₂ and/or cryogenic H₂. It is most preferred to preheat at least one of: O₂, H₂, and H₂O to a
10 temperature/pressure combination that is allows for efficient combustion. To manage this energy it is a preferred embodiment to heat at least one of the: O₂, H₂ or H₂O and/or any combination therein by heat exchange from at least one of: engine combustion energy, engine exhaust steam energy and radiant energy from an electrical resistant heating device and/or any combination therein. It is most preferred to preheat at least one of O₂
15 and H₂ from the energy of the environment prior to heating either: O₂, H₂ or H₂O by heat exchange from at least one of: engine combustion energy and engine exhaust steam energy. Since the heat capacity of water is much greater than that of water vapor (steam) and the latent heat of vaporization of water is a significant heat sink, it is a most preferred to heat the H₂O to a liquid state and not to a gaseous or fluid state (steam). Figure 19,
20 approximates the preferred embodiment of combustion heating the combustion mixture.

While not preferred, an embodiment of combustion of this invention would be to add H₂O with at least one of N₂ and Ar to the combustion chamber, utilizing as a heat sink the H₂O as well as N₂ and/or Ar to control the combustion temperature. While not preferred, an embodiment of combustion of this invention would be to utilize air instead
25 of O₂ as a source of O₂, whenever enough O₂ is not available, to combust with H₂ to produce H₂O as the primary combustion product, knowing that NO_x will be a secondary combustion product. The embodiment for the combustion of air and H₂ is preferably accomplished with H₂O added to the combustion chamber, thereby utilizing H₂O as a heat sink to reduce the combustion temperature and to produce steam. For brevity, the
30 methods, processes, systems and apparatus of the most preferred embodiment(s), the preferred embodiment(s) and the embodiment(s) of combustion will be herein after

referred to as WCT. Methods, processes, systems and apparatus for the WCT are approximated in figures 2 through 23A.

Cryogenic Distillation - Methods, processes, systems and apparatus for the WCT that incorporate Cryogenic distillation are approximated in Figures 5, 7, 8, 12, 15 and 17.

5 Cryogenic distillation principals incorporated into the WCT are to be those principles as are currently known in the art of cryogenic distillation. It is to be understood that per the Vapor-Liquid-Equilibrium diagram for each stage of distillation, the temperature of distillation is dependent upon the distillation pressure; higher separation pressures lead to higher separation temperatures. It is to be understood that the N₂/O₂ separation portion 10 contains two columns for the production of pure O₂, the second column may be eliminated to reach purities of O₂ which are less than that of pure O₂. A most preferred embodiment is to cool the air for distillation utilizing at least one of the Joule Thompson Effect and counter-current heat exchange. A preferred embodiment is to cool the air for distillation utilizing at least one of the Joule Thompson Effect and the vaporization of a 15 liquid. An embodiment is to cool the air for distillation utilizing at least one of the Joule Thompson Effect and the expansion of a gas doing work in an engine. A most preferred embodiment is to operate the first stage distillation column at 100 to 400 psia. A preferred embodiment is to operate the first stage distillation column at atmospheric to 3×10^6 psa (500 psia). A preferred embodiment of this invention is the use of recycled N₂ as a heat 20 sink, wherein at least one of: the recycled N₂ and recycled Ar can be used to cool at least one of: O₂ storage, H₂ storage, a cooling system of the combustion engine, a cooling system for electrolysis, the combustion engine, air in an air conditioning system, the gases/liquids within stages of cryogenic distillation of air and/or any combination therein. A most preferred embodiment of this invention is to cryogenically distill air into its 25 components of O₂, Ar and N₂, wherein the energy utilized for cryogenic separation is obtained from the WCT and wherein the separated O₂ is utilized as a fuel in the WCT.

Figures 5, 7, 8, 12, 15 and 17 approximate methods, processes, systems and apparatus of the WCT, wherein cryogenic distillation is used to separate air, wherein O₂ from said separation is used as a fuel in said WCT.

30 Membranes - Membranes, of either organic or inorganic construction, can effectively be used to separate air into O₂. Membrane separation principals incorporated into the WCT are to be those principles as are currently known in the art of membrane

separation. Staged membrane separation is preferred to produce the purest O₂. With the use of inorganic or organic polymer membranes, it is preferred to place an electrical potential across a membrane designed to hold an electrical potential to facilitate separation. It is most preferred to utilize at least one of organic and inorganic membranes to separate air, wherein the O₂ from said separation is used in the WCT. It is most preferred to utilize the energy of combustion from the WCT to provide mechanical energy, wherein said mechanical energy powers the flow of air through said membrane(s), wherein said membrane separates air, wherein the O₂ from said separation is used as a fuel in said WCT.

PSA - Whether of positive pressure or vacuum adsorption, PSA can effectively be used to separate air. PSA principals incorporated into the WCT are to be those principles as are currently known in the art of PSA. While there are material designs for the adsorption of O₂ as well as N₂, it is preferred to perform O₂ adsorption to minimize the size of the PSA. It is most preferred to utilize PSA to separate air, wherein the O₂ from said separation is used in the WCT. It is most preferred to utilize the energy of combustion from the WCT to provide mechanical energy, wherein said mechanical energy powers said PSA, wherein said PSA separates air, wherein the O₂ from said separation is used as a fuel in said WCT.

Figures 9, 10, 11, 13, 16 and 18 approximate methods, processes, systems and apparatus of the WCT, wherein at least one of organic membrane(s), inorganic membrane(s), PSA and/or any combination therein is used to separate air, wherein O₂ from said separation is used as a fuel in said WCT. In these figures, liquefaction of either H₂ or O₂ is a depicted option. It is preferred to utilized warm generated O₂ and H₂ in combustion as a first preference over liquefied O₂ or H₂; therefore, it is most preferred that any liquefaction be performed in storage as depicted in Figure 20.

This invention relates to chemical methods of producing H₂ from steam, since steam is the physical state of the water product from the WCT. Figures 4, 6, 8, 11, 12, 13, 14, 17 and 18 approximate methods, processes, systems and apparatus discovered in this aspect of the invention. This invention converts steam into H₂ utilizing the corrosion process. A preferred embodiment of this invention is to chemically convert the steam produced by WCT into H₂ utilizing the corrosion of at least one metal. A most preferred embodiment of this invention is to chemically convert the steam produced by WCT into

H₂, wherein said H₂ is produced by the corrosion of at least one metal, wherein that corrosion is enhanced by an electrical current in the metal(s). A preferred embodiment of this invention is to chemically convert the steam produced by WCT into H₂, wherein said H₂ is created by the corrosion of at least one metal, wherein said H₂ is used as a fuel in said WCT. A most preferred embodiment of this invention is to chemically convert the steam produced by WCT into H₂, wherein said H₂ is created by the corrosion of at least one metal, wherein said corrosion is enhanced by an electrical current in the metal(s), wherein said H₂ is used as a fuel in said WCT. In many of these figures, liquefaction of H₂ is a depicted option. It is preferred to utilized warm generated H₂ in combustion as a first preference over liquefied H₂; therefore, it is most preferred that any liquefaction be performed in storage as depicted in Figure 20.

This invention relates to electrolysis methods, processes, systems and apparatus to electrolytically convert H₂O into O₂ and H₂, wherein said O₂ and H₂ are used as fuel in the WCT. Electrolysis principals incorporated into the WCT are to be those principles as are currently known in the art of electrolysis. Figures 3, 6, 7, 8, 10 and 11 approximate the methods, processes, systems and apparatus for electrolysis in this invention. It is preferred to utilized warm generated O₂ and H₂ in combustion as a first preference over liquefied O₂ or H₂; therefore, it is most preferred that any liquefaction be performed in storage as depicted in Figure 20. As a most preferred embodiment, this invention stores energy by the potential chemical energy available in H₂O prior to electrolytic separation, as well as in O₂ and in H₂. Said O₂ and H₂ are available for the WCT and/or for a fuel cell to create electrical energy. As a most preferred embodiment, this invention stores energy by the potential chemical energy available in H₂O, wherein said H₂O can electrolytically be converted to O₂ and H₂, wherein said O₂ and H₂ are available for the WCT and/or for a fuel cell to create electrical energy. As a preferred embodiment, this invention stores energy by the potential chemical energy available in at least one of: H₂O, O₂ and H₂, as well as in batteries.

Since many types of combustion engines have a mechanical power output or mechanical energy rotating shaft, nearly all applications of this invention have the capability to convert available mechanical rotating energy into electrical energy. Conversion of available mechanical rotating energy is performed utilizing an electrical generation device; most preferably a generator, wherein it is preferred said electrical

energy is created. In cases wherein an alternator is used, an embodiment is to convert said electrical energy from an alternating current to a direct current. In cases where the WCT is performing work other than electrical, heat or steam generation, activation of said generator is preferably inversely proportional to the work or torque performed by the WCT. It is preferred that the mechanical rotating energy produced by the WCT enter a transmission, wherein said transmission engage in a manner that is inversely proportional to the torque and/or work output of said combustion system, wherein said transmission output mechanical rotating energy turn said generator to create said electrical energy. It is most preferred that said transmission engage a flywheel capable of storing rotational kinetic energy, wherein said flywheel turns said generator. Figures 3, 6, 7, 8, 10 and 11 approximate methods, processes, systems and apparatus to recycle mechanical energy as discovered in this invention. A preferred embodiment of this invention is the conversion of mechanical energy created by the WCT into electrical energy utilizing an electrical generator device. A most preferred embodiment is wherein said electrical energy is utilized in the electrolysis of H_2O into H_2 and O_2 . A most preferred embodiment of this invention is the conversion of mechanical energy created by the WCT into electrical energy utilizing an electrical generator device, wherein said electrical energy is utilized in the electrolysis of H_2O into H_2 and O_2 , wherein said H_2 and/or O_2 is used as fuel in said WCT.

20 Fuel Storage - By the gas law ($PV = nRT$), it can be surmised that the efficiency of compression and efficiency of storage for O_2 and/or H_2 is increased significantly if the O_2 and/or the H_2 is stored at cryogenic temperatures. It is preferred to store at least one of H_2 and/or O_2 is in a liquid state. Due to the explosive and flammable nature of H_2 and O_2 , it is preferred to utilize N_2 as a refrigerant for the storage of at least one of H_2 and O_2 . Due 25 to the rather extreme explosive nature of O_2 , it is preferred to limit the required storage of O_2 with preference to any of said O_2 generating technologies. To maintain fuel storage temperatures, it is preferred to operate a compressor for at least one of: liquefaction of O_2 , chilling of O_2 , liquefaction of H_2 , chilling of H_2 and/or any combination therein. It is most preferred that said compressor be powered by mechanical energy created by the 30 WCT. Figure 20, illustrates in block diagram form chilling and/or liquefaction of O_2 and/or H_2 .

Since nearly all applications of WCT have an engine exhaust, nearly all applications of this invention will have the ability to convert combustion exhaust steam energy. It is preferred to insulate the combustion engine and/or the steam turbine to retain as much energy as is practical to produce steam, thereby improving engine efficiency.

5 Conversion of said energy is preferably performed utilizing a steam turbine. Figures 3, 6, 7, 8, 10, 11, 14, 15, 16, 17 and 18 approximate the methods, processes, systems and apparatus to convert steam energy into electrical energy. Steam turbine principals incorporated into the WCT are to be those principles as are currently known in the art of steam turbine technology. A preferred embodiment of this invention is the conversion of

10 steam energy, wherein said steam energy is created by the WCT, wherein said steam energy is converted into electrical energy utilizing a steam turbine, wherein said steam turbine turns a generator creating said electrical energy. It is preferred that said electrical energy be regulated. In the case wherein an alternator is used, it is preferred that said electrical energy be converted from an alternating current to a direct current. A most

15 preferred embodiment of this invention is wherein at least a portion said electrical energy is utilized in the electrolysis of H_2O into H_2 and O_2 . A most preferred embodiment of this invention is the conversion of steam energy created by the WCT into electrical energy utilizing a steam turbine, wherein said steam turbine turns a generator device, wherein said generator device creates an electrical current, wherein at least a portion of said electrical current is utilized in the electrolysis of H_2O into H_2 and O_2 , wherein at least a portion of said H_2 and/or O_2 is used as at least a portion of the fuel in said WCT.

20

Since there are many applications of combustion engines performing some type of movement and/or many applications of combustion engines will have an available source of moving air or moving water, many applications of this invention will have the ability

25 to convert the energy of moving air or water. Figures 3, 6, 7, 8, 10, 11 and 22 approximate the methods, processes, systems and apparatus to convert moving air energy into electrical energy. A preferred embodiment of this invention is the conversion of the energy of moving air or water into electrical energy, wherein said electrical energy is created by a generator from the moving air or water utilizing a turbine which turns in

30 direct consequence of the moving air or water, wherein at least a portion of said electrical energy is utilized in the electrolysis of H_2O into H_2 and O_2 . It is preferred that said electrical energy be regulated. In the case wherein a generator is used, it is preferred that

said electrical energy be converted from an alternating current to a direct current. A most preferred embodiment of this invention is use of at least a portion of said H₂ and/or O₂ as fuel in said WCT.

5 Steam Turbine Method, Process and System

The energy of steam is measured in temperature and in pressure. Assuming saturated steam, steam energy is measured by pressure alone, i.e. the steam is normally termed 150, 300 or 400 psig steam, etc. Only in the case superheated steam is steam energy measured by both pressure and temperature. Steam loses temperature and 10 pressure as energy is used. Upon losing energy, steam temperature and pressure (usually just measured as pressure) reduces and the steam begins condensing water. Once all of the steam energy is depleted, there is no pressure or water vapor, just hot water. Using this knowledge, one may expect all electrical generation facilities to use every last thermal unit of steam. Such is not done, because such is not economical, given the 15 required investment. However, in the case of WCT, pollution control equipment is minimized and heat transfer equipment eliminated, thereby reducing investment and improving heat transfer. Heat transfer equipment is minimized or eliminated because the exhaust of the WCT Engine, steam, is directly transferred to the steam turbine. In the case of hydrocarbon combustion, energy of the hot gasses of combustion are transferred 20 via a heat exchanger to water, thereby creating steam, after which said hot gases are transferred to environmental protection equipment. Said heat exchanger(s) are normally called boilers. The discovered WCT eliminate the need for boilers to generate steam, thereby improving heat transfer, thereby improving steam generation efficiency.

It is preferred that steam turbine(s) of the present invention be installed in a 25 configuration, wherein the exhaust of the WCT drive said steam turbine(s), wherein condensation is removed. It is most preferred to transfer said condensation to electrolysis. Said removal of steam energy is most preferably performed in a staged system, wherein at each stage a portion of the energy of the steam is removed by a steam turbine and the resulting condensation is removed prior to the next steam turbine or stage 30 of energy removal. It is most preferred that all of the steam energy (pressure) be removed by the steam turbine/water removal system(s). It is preferred that at least a portion of the energy of the steam (pressure) be removed by the steam turbine/ water removal system.

Figures 21 and 21A approximates the methods, processes, systems and apparatus to convert steam energy into electrical energy, as discovered in this invention.

Air and Water Motion Turbine Method and System

5 The energy of moving air or water is measured in mass and velocity. Since the mass of air or water into an air or water turbine is equals the mass out of said turbine, the change in velocity is the measure of energy removal. That energy difference can be directly calculated using the laws of physics, specifically kinetic energy. However, it must be noted that the difference in velocity, the removed energy, which can be converted
10 into electrical energy by the turbine will have an opposite drag force. For a stationary combustion engine of the discovered WCT, said drag force can be counterbalanced by the support structure of the turbine. However, in transportation applications wherein the drag force is counter to the direction of motion, said drag force will reduce transportation efficiency. In transportation applications, the vehicle inherently contains a drag force that
15 reduces transportation efficiency. To the extent that said contained drag force can be utilized to convert moving air or water energy into electrical energy at a cost that is less than the energy losses in said contained drag force, is to the extent that said wind and/or water turbine will have practical application. One such application is that of a sail boat, wherein the drag force is in the same direction as the direction of motion. Figure 22
20 approximates the methods, processes, systems and apparatus to convert moving air energy into electrical energy, as discovered in this invention.

25 In water applications, wave energy (vertical energy) is much greater than the energy of the water's movement (horizontal energy). It is preferred in water applications that a generator be driven by the energy of the vertical wave movement. Figures 23 and 23A approximates the methods, processes, systems and apparatus to convert moving water energy into electrical energy, as discovered in this invention. It is preferred to use said electrical energy from said water energy to electrolytically convert H₂O into H₂ and O₂. It is most preferred to use said H₂ and/or said O₂ as fuel for said WCT.

30 Photovoltaic Cells

 In all applications of the discovered WCT, wherein light is available, it is an embodiment to utilize photovoltaic cells to create electricity. It is preferred to use said

electricity from said photovoltaic cells to electrolytically convert H₂O into H₂ and O₂. It is most preferred to use said H₂ and/or said O₂ as fuel for said WCT.

Fuel Cells

5 In all applications of the discovered WCT, wherein electricity is created, it is an embodiment to utilize fuel cells to create electricity. In such applications, a fuel cell would replace a battery for the storage of electrical energy. It is preferred to create said electricity with a fuel cell when the WCT Engine is not in operation. It is most preferred to utilize discovered WCT to create electricity.

10

Heating

The discovered WCT is especially suited for applications to generate heat. Heat generation may be performed using the discovered WCT in both industrial and in domestic applications. In the case of heating a gas or a liquid, the heat energy of the 15 discovered WCT can be effectively transferred via any heat exchange equipment as is known in the art of heat transfer.

20 In the case of heating air, wherein the combustion components are those discovered in the WCT, it is most preferred that the exhaust of combustion be discharged directly into said air to be heated. In the case of heating air to be used in an enclosed human, plant and/or animal application, wherein the combustion components are at least one of: O₂ and H₂; and O₂, H₂ and H₂O, it is most preferred that the exhaust of combustion discharge directly into said air to be heated, thereby providing humidified heated air.

25 In the case of heating water, wherein the combustion components are those discovered in the WCT, it is most preferred that the exhaust of combustion discharge directly into said water to be heated, wherein the water heater or hot water storage has a vent to release generated NO_x. In the case of heating water, wherein the combustion components are at least one of: O₂ and H₂; and O₂, H₂ and H₂O, it is most preferred that the exhaust of combustion can be discharged directly into said water to be heated, and 30 wherein the water heater or hot water storage has a pressure relief device, as is known in the art.

It is most preferred in heating applications that the combustion engine create electricity, as well as heat the subject gas and/or liquid. System configurations for the heating of a gas or a liquid are limited to the creativity of the designer; however, configurations approximating the discovered WCT System, wherein the heating of a gas or a liquid is performed is approximated in Figures 2 through 18, wherein heat transfer can be performed either in the exhaust of said combustion or in the block of said CE. (In this case cooling said CE is not a loss of efficiency since the removed heat has a purpose.)

Cooling

10 The discovered WCT is especially suited for applications to remove heat. Heat removal may be performed using the discovered WCT, wherein at least one of: cryogenic distillation is performed and/or the WCT provides mechanical energy and said mechanical energy powers a refrigeration system. In the case of cooling a gas or a liquid, the heat sink capability of the chilled N₂ from said cryogenic distillation is preferably transferred via heat exchange equipment, as is known in the art of heat transfer. In the case of cooling a gas or a liquid, a refrigeration unit is preferably used, wherein said refrigeration unit is powered by mechanical energy, wherein said mechanical energy is created by the WCT.

20 In the case of cooling air or water, it is most preferred that the heat sink capability of the chilled N₂ from said cryogenic distillation be transferred either directly to said air and/or via any heat exchange technology as is known in the art of heat transfer.

It is most preferred in cooling applications that the combustion engine create electricity, as well as cool the subject gas and/or liquid. System configurations for the cooling of a gas or a liquid are limited to the creativity of the designer.

25

Water Chemistry

Water is the most efficient and economical method of storing O₂ and/or H₂. Electrolysis of water is the preferred method of converting stored H₂ and/or O₂ as H₂O into combustible form. Electrolysis is best performed with a dissolved electrolyte in the water; the dissolved electrolyte or salt will improve conductivity in the water, thereby reducing the required electrical energy to perform electrolysis. In this invention it is an embodiment to perform electrolysis upon water that contains an electrolyte. In this

invention it is preferred to perform electrolysis upon water that contains a salt. However, many dissolved cation(s) and anion(s) combination(s) can precipitate over time reducing the efficiency of electrolysis. Due to inherent solubility, in this invention it is a preferred embodiment to perform electrolysis upon water that contains a Group IA/Group VIIA salt (including acids). Further, as temperature is increased, hard water contaminants may precipitate; therefore, it is preferred that the water of electrolysis be distilled or de-ionized prior to the addition of a Group IA/Group VIIA salt.

A dispersant is preferably added to water to prevent scale. Dispersants are low molecular weight polymers, usually organic acids having a molecular weight of less than 10, 25,000 and preferably less than 10,000. Dispersant chemistry is based upon carboxylic chemistry, as well as alkyl sulfate, alkyl sulfite and alkyl sulfide chemistry; it is the oxygen atom that creates the dispersion, wherein oxygen takes its form in the molecule as a carboxylic moiety and/or a sulfoxyl moiety. Dispersants that can be used in this invention which contain the carboxyl moiety are, but are not limited to: acrylic polymers, acrylic acid, polymers of acrylic acid, methacrylic acid, maleic acid, fumaric acid, itaconic acid, crotonic acid, cinnamic acid, vinyl benzoic acid, any polymers of these acids and/or any combination therein. Dispersants that can be used in this invention which contain the alkyl sulfoxyl or allyl sulfoxyl moiety include any alkyl or allyl compound, which is water soluble containing a moiety that is at least one of: SO, SO₂, SO₃, and/or any combination therein. Due to the many ways in which an organic molecule can be designed to contain the carboxyl moiety and/or the sulfoxyl moiety, it is an embodiment of this invention that any water soluble organic compound containing at least one of a carboxylic moiety and/or a sulfoxyl moiety. (This is with the knowledge that not all dispersants have equivalent dispersing properties.) Acrylic polymers exhibit very good dispersion properties, thereby limiting the deposition of water soluble salts and are most preferred embodiments as a dispersant in this invention. The limitation in the use of a dispersant is in the dispersants water solubility in combination with its carboxylic nature and/or sulfoxyl nature.

Water is inherently corrosive to metals. Water naturally oxidizes metals, some with a greater oxidation rate than others. To minimize corrosion, it is preferred that the water have a pH of equal to or greater than 7.5, wherein the alkalinity of the pH is from the hydroxyl anion. Further, to prevent corrosion or deposition of water deposits on steam turbines, it is preferred to add a condensation corrosion inhibitor to the water.

Corrosion inhibitors are added to water to prevent corrosion. Chelants can be used to prevent corrosion, as well as complex and prevent the deposition of many cations, including hardness and heavy metals. Chelants or chelating agents are compounds having a heterocyclic ring wherein at least two kinds of atoms are joined in a ring. Chelating is 5 forming a heterocyclic ring compound by joining a chelating agent to a metal ion. Chelants contain a metal ion attached by coordinate bonds (i.e. a covalent chemical bond is produced when an atom shares a pair of electrons with an atom lacking such a pair) to at least two nonmetal ions in the same heterocyclic ring. Examples of the number of chelants used for mineral deposition in the present invention are water soluble phosphates 10 consisting of phosphate, phosphate polymers, phosphate monomers and/or any combination thereof. The phosphate polymers consist of, but are not limited to, phosphoric acid esters, metaphosphates, hexametaphosphates, pyrophosphates and/or any combination thereof. Phosphate polymers are particularly effective in dispersing magnesium silicate, magnesium hydroxide and calcium phosphates. Phosphate polymers 15 are particularly effective at corrosion control. With proper selection of a polymer, along with maintaining an adequate polymer concentration level, the surface charge on particle(s) can be favorably altered. In addition to changing the surface charge, polymers also function by distorting crystal growth. Chelants lock the metals in the water into soluble organic ring structures of the chelants. Chelants provide reactive sites that attract 20 coordination sites (i.e. areas of the ion that are receptive to chemical bonding) of the cations. Iron, for example, has six coordination sites. All coordination sites of the iron ion are used to form a stable metal chelant. Chelants combine with cations such as calcium, magnesium, iron and copper that could otherwise form deposits. The resulting chelated particles are water soluble. The effectiveness of chelant(s) is limited by the 25 concentration of competing anions, alkalinity and temperature.

The effect of adding sufficient amounts of the number of chelant(s) by the present invention is to reduce available free metal ions in the water and therefore, reduce the phosphate demand. Phosphate, such as phosphoric acid and/or pyrophosphoric acid is used to complex or form metal phosphates, which are insoluble. In the preferred 30 embodiments, phosphate polymers, such as metaphosphate and/or hexametaphosphate is used as a corrosion inhibitor and as a chelant to prevent correspondingly any precipitation of calcium and/or magnesium, while providing corrosion control. Metaphosphate and/or

hexametaphosphate, as well as polymers based upon this chemistry, soften the water by removing the free calcium and/or magnesium ions from the water and by bringing the metal ions into a soluble slightly-ionized compound or radical. In addition, the water containing any excess metaphosphate and/or hexametaphosphate will actually dissolve 5 any phosphate or carbonate which may deposit. Metaphosphate and/or hexametaphosphate do not throw the metal ions out of solution as is the case of usual water softening compounds, but rather lock up the metal ions in a metaphosphate and/or a hexametaphosphate complex molecule; these molecules provide a one or two molecule thickness coating on metal surfaces to limit metal corrosion. This is particularly 10 important for heavy metal materials.

Operating Pressure Relief

The WCT Engine will have applications wherein the recycling or re-use of the exhaust gasses of combustion create high operating pressures. Further, it is very feasible 15 that there may be unintended operating situations, wherein the operating pressure becomes greater than the design pressure of the equipment employed; any such situation can be a significant safety issue. In the case of the internal combustion engine, a significant industry paradigm shift may be required for the industry to even consider trapping and recycling combustion engine exhaust gases. The discovered WCT will 20 contain H₂, O₂ and H₂O, and additionally N₂ in some aspects, at various pressures in many aspects of the invention. To ensure that the WCT operates safely, in the event of an equipment operating failure or of equipment operating in excess of the intended pressure, pressure relief is preferred. Pressure relief can limit the potential event of a catastrophic failure. It is preferred that pressure relief device(s) be installed 25 throughout the WCT as those devices are known in the art and as are normally located via a Failure Mode and Effect Analysis and/or a Fault Tree Analysis. Example devices include pressure relief valves, rupture discs and pressure relief control loops. It is most preferred that a pressure relief device be installed downstream of any compression generating portion of the WCT. As such, it is most preferred that pressure relief device(s) 30 be installed immediately downstream of any compressor and in the combustion engine exhaust. Figures 2 through 18 approximate the location of pressure control/relief in the combustion engine exhaust. Figure 24 approximates pressure relief designs.

WCT Engine and Apparatus

Referring to figures 3 through 18, a combustion engine (CE) is symbolically shown for receiving as fuel H₂ and at least one of: O₂ and air. Said combustion engine may be of any type, wherein combustion is performed to generate at least one of: 5 mechanical torque, heat, electricity and/or any combination therein. It is preferred that H₂O be received in the combustion chamber, along with said fuel, said H₂O is to be termed combustion H₂O.

H₂ flowing to CE is to have a flow. O₂ flowing to CE to have a flow. Air flowing to CE is to have a flow. Means to measure said H₂ flow, measure said O₂ flow and 10 measure said air flow are to be provided such that a proportional signal in relation to flow is sent to the CE controller (CONT) from each of said H₂ flow measuring device, said O₂ flow measuring device and said air flow measuring device. H₂ flowing to CE is to have flow valve(s). O₂ flowing to CE to have flow control valve(s). CONT is to have as input said H₂ flow signal, said O₂ flow signal and said air flow signal. Said controller is to 15 receive an input signal from an external source indicating the combustion setpoint. Said controller is to compare said combustion setpoint to said H₂ flow signal, sending a proportional signal to said H₂ flow control valve that is in proportion to the difference in the combustion setpoint and the H₂ flow signal, thereby proportioning said H₂ flow control valve. CONT is to compare said O₂ flow signal and said air flow signal to an 20 H₂/O₂ ratio setpoint, providing a proportional signal to an O₂ flow control valve and to an air flow control valve, wherein: said H₂ flow, said O₂ flow and said air flow are such that the molar ratio of H₂/O₂ is approximately 2:1. In the case wherein said O₂ flow control valve signal is not near approximately 100%, CONT sends a signal to close said air flow control valve. In the case wherein said O₂ flow control valve signal is near approximately 25 100%, CONT compares said O₂ flow signal and said air flow signal to said H₂/O₂ ratio setpoint obtaining an air flow difference, sending a proportional signal to said air flow control valve that is in proportion to said difference, thereby proportioning said air flow control valve.

To conserve energy, as depicted in Figure 20, it is preferred that the H₂ flow 30 control valve(s) consist of a two staged system of flow control valves. The first H₂ flow control valve, downstream of generated H₂ and downstream of H₂ storage is to control H₂ flow to CE. The second H₂ flow control valve (for installations that have generated H₂) is

to be located from the generated H₂ line and be located in the H₂ line flow from H₂ storage. The second H₂ flow control valve is to remain closed until the first H₂ control valve is near approximately 100 % open (thereby assuring full usage of generated H₂ prior usage of stored H₂) at which time the second H₂ flow control valve will begin 5 opening to supply H₂ from storage.

To conserve energy, as depicted in Figure 20, it is preferred that the O₂ flow control valve(s) consist of two staged flow control valves. The first O₂ flow control valve, downstream of generated O₂ and downstream of O₂ storage is to control O₂ flow to CE. The second O₂ flow control valve is to be located from the generated O₂ line and be 10 located in the O₂ line flow from O₂ storage. The second O₂ flow control valve is to remain closed until the first O₂ control valve is near approximately 100 % open (thereby assuring full usage of generated O₂ prior usage of stored O₂) at which time the second O₂ flow control valve will begin opening to supply O₂ from storage.

15 It is preferred that a source of coolant flow to and/or through the block of CE. It is preferred that a temperature measurement device have a means of measuring combustion temperature and/or CE block temperature near the combustion chamber(s) of CE. Means to measure said combustion H₂O flow and measure said combustion temperature are to be provided such that a proportional signal is sent to a controller 20 (CONT) from each of said combustion H₂O flow measuring device and said combustion temperature measuring device. CONT is to have as input said combustion H₂O flow signal, afore said H₂ flow signal and said temperature signal. It is preferred that CONT have a hot temperature setpoint, a coolant temperature setpoint, a warm temperature setpoint and an H₂/H₂O ratio setpoint. It is preferred that CONT compare afore said H₂ 25 flow signal and said combustion H₂O flow signal to said H₂/H₂O ratio setpoint, in combination with comparing said temperature signal to said warm temperature setpoint, said coolant temperature setpoint, said hot temperature setpoint and provide a proportional signal to said combustion H₂O flow control valve and to said coolant flow control valve.

30 In the case wherein said temperature signal is less than said warm temperature setpoint, less than said coolant temperature setpoint and less than said hot temperature setpoint, it is preferred that CONT send a signal to said coolant flow control valve to

close said coolant flow control valve; and send a signal to said combustion H₂O flow control valve to close said combustion H₂O flow control valve.

In the case wherein said temperature signal is equal to or greater than said warm temperature setpoint, less than said coolant temperature setpoint and less than said hot temperature setpoint, it is preferred that CONT send a signal to said coolant flow control valve to close said coolant flow control valve; and send a signal to said combustion H₂O flow control valve, wherein said signal is proportional to the difference between said measured temperature signal and the warm temperature setpoint, and wherein the H₂/H₂O ratio is greater than said H₂/H₂O ratio setpoint, thereby proportioning said combustion H₂O flow control valve.

In the case of said temperature signal greater than said warm temperature setpoint, equal to or greater than said coolant setpoint and less than said hot temperature setpoint, it is preferred that CONT send a signal to the combustion H₂O flow control valve, wherein the H₂/H₂O ratio is equal to said H₂/H₂O ratio setpoint, thereby proportioning said combustion water flow control valve; and send a signal to said coolant flow control valve, wherein said signal is proportional to the difference between said temperature signal and said coolant setpoint, thereby proportioning said coolant flow control valve.

In the case wherein the temperature signal is greater than said warm temperature setpoint, greater than said coolant setpoint and equal to or greater than said hot temperature setpoint, it is preferred that CONT send a signal to open the combustion H₂O flow control valve 100%, which obtains a H₂/H₂O ratio less than said H₂/H₂O setpoint; and send a signal in proportion to the difference between the temperature signal and said coolant setpoint to said coolant flow valve, thereby proportioning said coolant flow control valve; and send a signal to said H₂ flow control valve, thereby closing said H₂ flow control valve; and send a signal to said O₂ flow control valve, thereby closing said O₂ flow control valve; and send a signal to said air flow control valve, thereby closing said air flow control valve.

It is most preferred that the WCT Engine operate at a temperature between said warm temperature setpoint and said coolant temperature setpoint. It is preferred that energy not leave the WCT engine via coolant. It is most preferred that required engine cooling be performed by the addition of combustion H₂O to the combustion chamber(s).

Said WCT Engine is to preferably obtain O₂ from at least one of: O₂ storage,

15 cryogenic distillation, membrane separation, PSA, electrolysis of H₂O and/or any combination therein. Said cryogenic distillation is to obtain O₂ from at least one of air and/or electrolysis of H₂O. Said membrane separation and/or said PSA is preferably to obtain O₂ from air. Said cryogenic distillation and/or said membrane separation and/or said PSA is to preferably be powered by said WCT Engine. Said O₂ storage is to preferably be performed at cryogenic temperatures. The mechanical energy for said cryogenic storage is preferably created by said WCT Engine.

10 Said WCT Engine is preferably to obtain H₂ from at least one of: H₂ storage, steam corrosion of a metal(s), electrolysis of H₂O and/or any combination therein. Said steam, to produce H₂ from said corrosion, is preferably an exhaust product of said WCT Engine. Said H₂ storage is to preferably be performed at cryogenic temperatures. The mechanical energy for said cryogenic storage is preferably created by said WCT Engine.

15 Afore said electrolysis of H₂O is preferably to obtain electrical energy for electrolysis from a generator driven by at least one of: a steam turbine, mechanical rotating energy, an air turbine powered by the energy of moving air, a water turbine powered by the energy of moving water and/or any combination therein and/or photovoltaic cell(s). It is preferred that said electrical energy be regulated. In the case wherein an alternator is used, it is preferred that said electrical energy be converted from an alternating current to a direct current. Said steam turbine is most preferably powered by steam generated by afore said WCT Engine. Said mechanical rotating energy is preferably powered by afore said WCT Engine.

20 The WCT Engine is to preferably generate mechanical energy in the form of torque. It is preferred that said mechanical energy turn a generator, wherein said generator create electrical energy. Exhaust from said WCT Engine is preferably to turn a steam turbine, wherein said steam turbine turns a generator, wherein said generator creates electrical energy. It is preferred that at least a portion of said electrical energy is used to electrolytically convert H₂O into H₂ and O₂. It is most preferred to use a portion of said H₂ and/or said O₂ as fuel for said WCT Engine.

25 Materials of construction for the WCT Engine, the fuel and energy management systems and apparatus are to be those as known in the art for each application as said application is otherwise performed in the subject art. For example, various composite and metal alloys are known and used as materials for use at cryogenic temperatures.

Various composite and metal alloys are known and used as materials for use at operating temperatures of over 260°C (500°F). Various ceramic materials can be conductive, perform at operating temperatures of over 1100°C (2000°F), act as an insulator, act as a semiconductor and/or perform other functions. Various iron compositions and alloys are known for their performance in combustion engines that operate approximately in the 90 to 800°C (200 to 1500°F) range. Titanium and titanium alloys are known to operate over 1100 and 1600°C (2000 and 3000°F). Tantalum and tungsten are known to operate well over 1600°C (3000°F). It is preferred to have at least a portion of the construction of the WCT Engine contain an alloy composition wherein at least one of: a period 4, period 5 and/or a period 6 heavy metal is used, as that metal(s) is known in the art to perform individually or to combine in an alloy to limit corrosion and/or perform in a cryogenic temperature application and/or perform in a temperature application over 500°C (1000°F). While aluminum is lightweight and can perform limited structural applications, aluminum is limited in application temperature. Due to the operating temperatures involved in the WCT Engine, thermoplastic materials are not preferred unless the application of use takes into account the glass transition temperature and the softening temperature of the thermoplastic material.

Example 1

A traditional gasoline internal combustion engine obtains approximately 8.5 km l⁻¹ (20 miles per gallon). Performing an energy balance on the engine, according to Figure 2:

$$\begin{aligned}
 E_F &= E_W + E_{EX} + E_C + E_{flic} + E_C \\
 E_F &= \approx 20\% E_F + \approx 35\% E_F + \approx 35\% E_F + \approx 9\% E_F + \approx 1\% E_F \\
 E_F &= E_W + \approx 80\% E_F \text{ in energy losses for internal CE(s).} \\
 E_F &= 20 \text{ mpg} + 80\% E_F
 \end{aligned}$$

Again,

$$E_F = E_W + E_{EX} + E_C + E_{flic} + E_C$$

Assuming: 1) complete engine insulation, 2) a steam turbine with 80% efficiency, 2) a generator with 90% efficiency and 3) an electrolysis unit with 80% efficiency turns E_{EX} and E_C , E_{WCT} , into approximately 30% E_F

Using WCT,

$$\begin{aligned}
 E_F &= E_W + 0.30 E_F + \approx 9\% E_F + \approx 1\% E_F \\
 E_W (\text{WCT}) &= 50\% E_F
 \end{aligned}$$

Example 2

Referencing CRC Handbook of Chemistry and Physics, the total available combustion energy for n-Octane is approximately 5440 kJ/mole (1300 kcal/mole); at 114 kg/kg mole (114 lb/lb mole) $E_F = 105 \text{ KJ/kg}$ (11.4 kcal/lb). (This excludes endothermic losses in the formation of NO_x .) Further, the density of n-Octane is approximately 803 kg/m^3 (6.7 lb/gallon), which leads to energy figures for n-Octane in the average automobile:

$E_F \approx 424000 \text{ km/m}^3 = 53.1 \text{ km/kg} = 105 \text{ KJ/kg}$ (100 mpg = 15 mile/lb. = 11.4 kcal/lb.); $E_w = 8480 \text{ mpg} = 10.62 \text{ km/kg} = 21.16 \text{ KJ/kg}$ (20 mpg = 3 mile/lb. = 2.3 kcal/lb). The total available energy for the combustion of hydrogen is 284 KJ/mole (68 kcal/mole); at $\frac{1}{2} \text{ lb/lb mole}$

10 2 kg/kg mole

$E_F = 312.8 \text{ KJ/kg}$ (34 kcal/lb). Therefore, on a mass basis, $H_2 = 312.8/105$ (34/11.4) ≈ 3 times more energy per kg (pound).

Therefore, using WCT, H_2 and O_2 are $50\% / 20\% = 2.5$ times more efficient. Correlating, energy figures for WCT in the average automobile:

15 First, the fuel availability must be calculated. H_2 is 100% as delivered. Since cryogenics are at least approximately 16% efficient, the production of O_2 is estimated to be 16% efficient.

$$\frac{2}{3} \times 1 + \frac{1}{3} \times 0.16 \approx 70\%$$

(Therefore, approximately 30% of the energy of the H_2 and O_2 is used to generate O_2 .)

20 $E_F \approx \frac{53.1 \text{ km/kg (15 mile/lb.)} \times 0.70 \times 312.8 \text{ KJ/kg (34 kcal/lb.)} H_2 \times 2.5}{11.4 \text{ kcal/lb. n-Octane}} = 109 \text{ km/kg (31 m/lb.)} H_2 \approx 53.1 \text{ km/kg (15 mile/lb.)} H_2$

(Note: Every kg (lb.) of H_2 requires $\frac{1}{2}$ kg(lb.) of generated O_2 .)

Example 3

According to the Chemical Market Reporter, H_2 has a current market price of approximately \$1.1/kg (\$0.50/lb.) and gasoline has a price of approximately \$422/m³ (\$1.60 per gallon) or approximately \$0.52/kg (\$0.24 per pound). Utilizing traditional hydrocarbon combustion technology in transportation, the cost per mile for fuel is:

25 $\frac{\$0.52/\text{kg} (\$0.24 \text{ per lb.})}{10.6 \text{ km/kg (3 mile per lb.)}} = \$0.05/\text{km} (\$0.08 \text{ per mile})$ for gasoline

Utilizing the WCT with the current cost of H_2 , the cost per mile for fuel is:

$\frac{\$1.1/\text{kg} (\$0.50 \text{ per lb.})}{53.1 \text{ km/kg (15 mile per lb.)}} = \$0.02 \text{ per km} (\$0.03 \text{ per mile})$

Example 4

Electrical power plants currently produce electricity using a natural gas turbine followed by a steam turbine, wherein the energy for steam generation is transferred via a boiler from the exhaust gas of the natural gas turbine. As is typical in the industry:

5

- The efficiency of combustion is approximately 99 percent.
- The efficiency of the natural gas turbine is approximately 20 percent.
- The efficiency of the boiler is approximately 85 percent.
- The efficiency of the steam generator is approximately 90 percent.

Utilizing the above, the efficiency of electricity generation is approximately:

10
$$0.99 \times 0.20 + 0.99 \times 0.20 \times 0.85 \times 0.90 = 35 \text{ percent}$$

For WCT utilizing the configuration in Figure 23A, appropriate assumptions for efficiency would be approximately:

15

- The efficiency of combustion near 99 percent.
- The efficiency of O₂ generation (cryogenics are 16%) near 16 percent.
- Hydrogen is delivered, thereby having 100% delivery efficiency.
- Heat loss of water at exhaust (649°C - 100°C (1200°F - 212°F) ≈ 80%) near 80 percent.
- Friction losses near 12 percent.

Utilizing the above, the efficiency of electricity generation is approximately:

20
$$0.99 \times (2/3 \times 1 + 1/3 \times 0.16) \times 0.80 \times 0.88 = 50 \text{ percent}$$

Utilizing the above, incorporating:

- A H₂ price of approximately \$1.1/kg (\$0.50 per pound).
- A natural gas price of approximately \$214/thousand cubic metres (\$6.00 per thousand cubic feet).
- A natural gas energy value of approximately 888 KJ/mole (212 kcal/mole).

The cost of electricity production for WCT on a kcal basis is:

25
$$\$1.1/\text{kg} (\$0.50/\text{lb.}) \times 0.50/313 \text{ KJ/kg (34 kcal/lb.)} = 0.00176/\text{KJ} (\$0.007/\text{kcal})$$

The cost of electricity production for a traditional natural gas plant on a KJ (kcal) basis is:

30 First convert cubic metres (cubic feet) to kg (pounds) at STP and convert to KJ/kg kcal/lb.:

28 m³ (1000 cubic feet (tcf))/kg (360 cubic feet per lb.) mole = KJ/kg 1.3 kg. mole(2.8 lb. mole)

$$1.3 \text{ kg/mole (2.8 lb. mole} \times 16 \text{ kg/kg mole (16 lb./lb. mole)} = 20.8 \text{ kg (45 lb.)}$$

$$888 \text{ KJ/mole (212 kcal/mole)/16kg/kg mole (16lb./lb. Mole)} = 55.5 \text{ KJ/kg (13.25 kcal/lb.)}$$

Second, estimate economics:

$$\$168 \text{ per cubic meter/572 kg per cubic meter} (\$6.00 \text{ per tcf/45 lb. per tcf}) \times 0.36/12 \text{ KJ/kg (13.25 kcal/lb.)} = \$0.419/\text{KJ} (\$0.010/\text{kcal})$$

Example 5

In residential heating, natural gas is often used. Referencing above, the cost of natural gas heating, assuming 80% heat transfer efficiency is:

5 \$224 per cubic metre/572 kg per cubic metre (\$8.00 per tcf/45 lb. per tcf) X 0.80/121
KJ/kg (13.25 kcal/lb.) = \$0.046/KJ (\$0.011/kcal)

For WCT using membranes and referencing above:

\$1.1/kg (\$0.50/lb.) X (2/3 X 1 + 1/3 X 0.40) X 0.80/312 KJ/kg (34 kcal/lb.) =
\$0.037/KJ (\$0.009/kcal)

CLAIMS:

1. A combustion system, comprising a fuel mixture of oxygen, as O_2 , hydrogen, as H_2 , wherein at least a portion of said oxygen is obtained by the separation of air, and
5 wherein said separation of air is carried out by a method selected from the group consisting of (a) cryogenic air separation, (b) membrane air separation and (c) pressure swing absorption air separation, and combinations thereof, wherein at least a portion of the energy of combustion powers at least a portion of the air separation, and wherein combustion occurs in a combustion chamber and combustion
10 temperature is at least partially controlled with the addition of water to the combustion chamber.
2. A combustion engine comprising a combustion chamber, wherein a mixture of oxygen, as O_2 , and hydrogen, as H_2 , are combusted, wherein at least a portion of said
15 oxygen is obtained by the separation of air and wherein the separation of air is carried out by a method selected from the group consisting of: (a) cryogenic air separation, (b) membrane air separation, and (c) pressure swing absorption air separation and combinations thereof and wherein at least a portion of the energy of combustion powers at least a portion of said air separation, and wherein the temperature of
20 combustion is at least partially controlled with the addition of water to said combustion chamber.
3. A method of combustion, comprising using a fuel mixture of oxygen, as O_2 and hydrogen, as H_2 , wherein at least a portion of said oxygen is obtained by the separation
25 of air and wherein said separation of air is carried out by a method selected from the group consisting of (a) cryogenic air separation, (b) membrane air separation, (c) pressure swing absorption air separation and combinations thereof and wherein at least a portion of the energy of combustion powers at least a portion of said air separation, and wherein combustion occurs in a combustion chamber and the
30 temperature of combustion is at least partially controlled with the addition of water to said combustion chamber.
4. A system of claim 1 or an engine of claim 2 or a method of claim 3 wherein the steam produced by combustion turns at least one steam turbine, and wherein said
35 steam turbine(s) turn a generator to create electrical energy.

5. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein mechanical rotating energy is created by said combustion, and wherein said mechanical rotating energy turns a generator to create electrical energy.
- 5
6. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein nitrogen or argon is in said fuel.
- 10
7. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein at least a portion of the steam produced by combustion is converted to hydrogen by the corrosion of at least one metal.
8. The system or engine or method of claim 7, wherein the production of hydrogen is increased by an electrical current in said metal(s).
- 15
9. The system or engine or method of claim 7 or claim 8, wherein at least a portion of said hydrogen is used as part of said fuel mixture.
10. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein a generator turns due to the movement of air or water, and wherein said generator creates electrical energy, and wherein said electrical energy is at least partially utilised in the electrolysis of water to hydrogen or oxygen, and wherein at least a portion of said hydrogen and/or at least a portion of said oxygen is used as part of said fuel mixture.
- 20
- 25
11. The system or engine or method of claim 4 or claim 5, wherein said electrical energy is at least partially used in the electrolysis of water to produce hydrogen and oxygen.
- 30
12. The system or engine or method of claim 11, wherein at least a portion of said hydrogen and/or at least a portion of said oxygen is used as part of said fuel mixture.
13. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein a photovoltaic cell creates electrical energy, and wherein said electrical energy

wherein at least a portion of said hydrogen and/or at least a portion of said oxygen is used as part of said fuel mixture.

14. The system of claim 1 or the engine of claim 2 or the method of claim 3 wherein
5 during said separation of air, argon is substantially removed from said oxygen.

15. The system of claim 1 or the engine of claim 2 or the method of claim 3,
wherein nitrogen from air separation is used to cool any portion of: stored oxygen,
stored hydrogen, an electrolysis system, said combustion and any combination thereof.

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16. The system of claim 1 or the engine or claim 2 or the method of claim 3,
wherein separation of air is carried out by cryogenic air separation and nitrogen from
air separation is used to cool said cryogenic air separation system.

15

17. The system of claim 1 or the engine of claim 2 or the method of claim 3,
wherein nitrogen from said separation of air is at least partially used to cool air or
water.

20

18. The system of claim 1 or the engine of claim 2 or the method of claim 3 wherein
at least one of: a corrosion inhibitor, a chelant, a dispersant and any combination
thereof is added to the water that is added to the combustion chamber.

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19. The system of claim 1 or the engine of claim 2 or the method of claim 3 wherein
at least one of oxygen and hydrogen is stored in a liquid state, the liquid state being
achieved by liquefaction.

30

20. The system or engine or method of claim 19, wherein liquefaction is effected
by at least one compressor and said compressor(s) is powered by at least one of: a
fuel cell and said combustion.

21. The system or engine or method of claim 20, wherein said compressor(s) is
powered by a fuel cell and said fuel cell is powered by at least one of oxygen and
hydrogen.

22. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein at least one of hydrogen, oxygen and water are preheated prior to combustion with the energy from at least one of: ambient temperature, said combustion, said combustion exhaust, an electrical radiant heat source and/or any combination thereof.

5

23. The system or engine or method of claim 5, wherein said mechanical rotating energy from combustion enters a transmission, wherein said transmission engages in a manner that is inversely proportional to the torque and/or work output of said combustion, wherein said transmission output mechanical rotating energy turns said generator to create said electrical energy.

10

24. The system or engine or method of claim 23, wherein said transmission engages a fly wheel capable of storing rotational kinetic energy, wherein said fly wheel turns said generator.

15

25. The system of claim 1 or the engine of claim 2 or the method of claim 3, wherein a pressure control device is installed in the combustion exhaust.

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26. A system of claim 1 or the engine of claim 2 or the method of claim 3, wherein the combustion exhaust is used to heat at least one of a gas and a liquid.

27. A system or engine or method of claim 26 in which the combustion exhaust is used to heat either air or water.

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28. The system or engine or method of claim 27 in which the combustion exhaust is discharged directly into said air or water.

29. The system of claim 1, wherein the system is insulated.

30

30. The engine of claim 2, wherein the engine is insulated.

31. The method of claim 3, wherein the combustion apparatus is insulated.